CONSULTANT REPORT

PIER
Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

Strategic Energy Research

ENERGY SOURCE STABILIZER

Gray Davis, *Governor*

SEPTEMBER 1999

CALIFORNIA ENERGY COMMISSION

RESOURCES AGENCY

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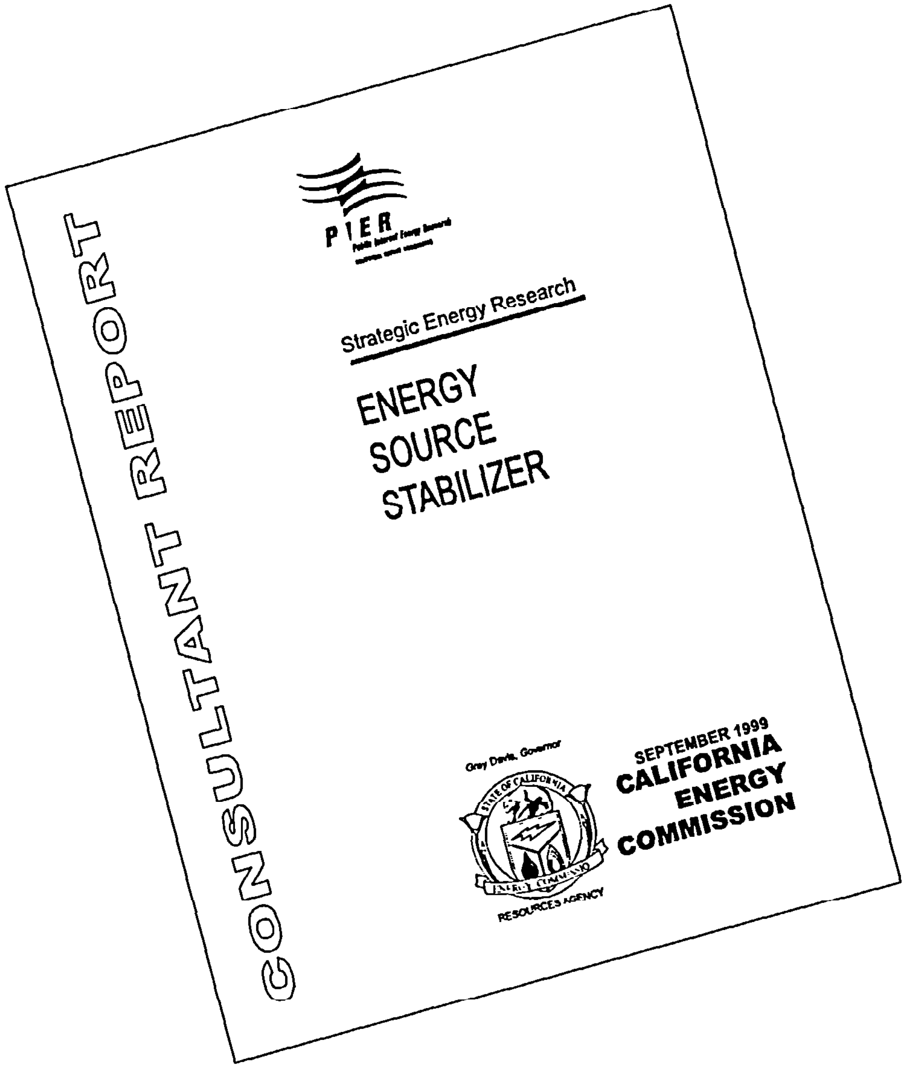
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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million through the Year 2001 to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial / Agricultural / Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research.

In 1998, the Commission awarded approximately $17 million to 39 separate transition RD&D projects covering the five PIER subject areas. These projects were selected to preserve the benefits of the most promising ongoing public interest RD&D efforts conducted by investor-owned utilities prior to the onset of electricity restructuring.

Edison Technology Solutions (ETS) is an unregulated subsidiary of Edison International and an affiliate of Southern California Edison Company (SCE). As a result of a corporate restructuring, ETS ceased active operations on September 30, 1999. ETS' remaining rights and obligations were subsequently transferred to SCE.

What follows is the final report for the Energy Source Stabilizer project, 1 of 10 projects conducted by ETS. This project contributes to the Strategic Energy Research program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

During certain times of the year, the energy imports into California are limited by system stability considerations. One of the major concerns during system stability studies is undampened inter-area oscillation which limits the amount of energy that can be imported into California.

This project is designed to support the Public Interest Energy Research (PIER) objective of improving the reliability and quality of California's electricity, through applications of an Energy Source Stabilizer (ESS). The ESS combines an Excitation Power System Stabilizer (EPSS) which functions through the generator excitation system, and a Governor Power System Stabilizer (GPSS) which works on the governor system and modulates the real power output of the generator.

Objectives:

- Install and test an ESS.
- Monitor the performance of the ESS to improve the reliability of electric transmission and distribution facilities.
- Demonstrate that during Western Systems Coordinating Council (WSCC) system disturbances of inter-area oscillations between 0.3 Hz to 0.7 Hz, generator real power output can be modulated to within +10 MW.

Outcomes:

- GPSS were installed and tested on the High Pressure (HP) generators, and EPSS were installed on the HP and Low Pressure (LP) generators of units 5 and 6 of the Alamitos Generating Station; both units have a HP and a LP generator.
- Performance of the Integrated Power System Stabilizer (IPSS), another name for ESS, was monitored on unit 5 and 6 from March of 1998 through August of 1999. During this period, the EPSS portion of the IPSS installed on both HP and LP generators triggered several data records. The GPSS portion of the IPSS on the HP generator was also triggered and operated.
- Successful demonstration of generator real power output modulation to within +10 MW is represented in this report.

Conclusions:

- With future IPSS installations in WSCC there is a potential to increase the amount of imports into California on certain paths by 5 to 10 percent. This provides the economic and environmental benefits of this project.

Recommendations:

- The stabilizer units are equipped with extensive self-checking and data recording features. A process needs to develop in which this data can be made helpful in identifying and diagnosing a variety of generator control problems and for reporting to regulatory authorities with the goal of improving inter-area system reliability.
- Continue to monitor ESS performance to validate the design during various disturbances. Modify ESS design criteria and trigger thresholds, if necessary.
- After successful demonstration in the field, survey the generating facilities in the WSCC to identify candidate generators for ESS installation.
- Conduct WSCC system simulation studies to determine optimal location of the ESS to damp out inter-area oscillations and improve system reliability.

Abstract

Reliability of the inter-area power transmission system is improved by reducing unstable conditions. Stabilizers are devices used to dampen unstable oscillations in electrical systems. Energy Source Stabilizers (ESS) are devices applied to generators to improve stability. This Energy Source Stabilizer Project was funded by the California Energy Commission and installed on Units 5 and 6 of the Alamitos generating station located near Long Beach, California. Units 5 and 6 are both rated at 480 Megawatts (MW). The Alamitos generating station has a combined generating capacity of approximately 2,000 MW. The facility is owned by AES Alamitos, L.L.C.

Energy Source Stabilizers combine an Excitation Power System Stabilizer (EPSS) and a Governor Power System Stabilizer (GPSS). The EPSS functions through the generator excitation system whereas the GPSS works on the governor system and modulates the power output of the generator. Both Units 5 and 6 have Low Pressure (LP) and High Pressure (HP) generators. GPSS were installed on the HP generators and EPSS were installed on the LP and HP generators. During the course of this project IPSS performance data was collected and analyzed from Units 5 and 6.

During this project, supplementary damping was provided to inter-area mode oscillations through the modulation of both the excitation current from the exciter and the mechanical power supply from the turbine. The modulation of mechanical power was accomplished by the electronic governor steam valve control logic. A low-level electronic signal supplied to the valve controller was used to modulate valve position at the low frequencies associated with the inter-area modes of oscillation.

ESS testing was conducted on each unit to verify that both EPSS and GPSS control units were operating as designed. Tests were conducted to verify that the interface between the operator and unit control systems, automatic voltage regulator (AVR), and governor valve controls were configured correctly and operating as expected. The AVR and associated EPSS functions were tuned to provide supplementary damping for a broad range of local and inter-area mode frequencies. Operation of EPSS and GPSS functions were demonstrated through local testing. Finally, the data recording facility of the units was configured to capture system events, which would be analyzed to assess the performance of both stabilizing functions during actual operation.

This project monitored the performance of ESS on Units 5 and 6 from March of 1998 through August of 1999. Data records include Megawatt (MW) load on HP, generator terminal voltage, generator field voltage, GPSS trigger signal, GPSS output, EPSS sensing frequency, and EPSS output which was captured due to a system disturbance that exceeded EPSS output thresholds. The EPSS portion of the IPSS on both the HP and LP generators has triggered several data records. The GPSS portion of the ESS on the HP generator has also triggered and operated.

1.0 Introduction

Synchronous generators connected to large power systems participate in numerous electromechanical modes of oscillation. Electromechanical modes of oscillation involve the exchange of energy between rotating masses of synchronous machines at different locations in a power system. These rotating masses of synchronous machines are composed of generator rotors, turbine blades, interconnecting shafts, and couplings. Oscillation modes can be identified as small amplitude periodic oscillations in the rotor speed and electrical power output. On average, the electrical power output of the generator must equal the power input of the turbine, minus losses. The output power can be modulated about the average value, as the unit accelerates or decelerates relative to the synchronous speed of the system. Even small changes in the rotor speed can result in significant variations in electrical power. The normal range of frequencies of these electromechanical modes is 0.2 Hz to 2.0 Hz. Frequencies below 1.0 Hz are normally associated with inter-area modes, in which large groups of units in one area oscillate coherently against large groups of units in another area. On the Western System Coordinating Council (WSCC), the two dominant inter-area modes are at frequencies of 0.7 Hz between California and Arizona and 0.3 Hz between southwest and northwest California.

The degree to which each generator participates in each mode of oscillation is dependent on synchronizing and damping forces acting on the rotor of the machine. Numerous factors affect both of these components including generator parameters, electrical interconnection to the system, and the tuning of the exciter's closed-loop terminal voltage regulator. Tuning of excitation systems can be used to increase the synchronizing torque acting on the rotor, however this normally leads to a reduction in the damping torque acting on the unit. Supplementary damping can be provided through the excitation system using a conventional power system stabilizer (PSS). The excitation PSS operates by modulating the generator's electrical torque through changing field voltage and current as machine speed varies. This form of stabilizer can be very effective in improving damping, although its effectiveness is a function of the type of excitation system used with the generator.

1.1. Background

Southern California Edison installed a 10 MW Battery Energy Storage System (BESS) at its Chino Substation facility in 1988. The BESS facility was in operation from 1988 to 1996. SCE installed an Energy Source Power System Stabilizer (ESPSS) to test the concept of damping power system swings using ESPSS. The ESPSS basically modulates the power output/input of the energy storage batteries to respond to system frequency deviations caused by power system oscillations. The ESPSS was designed to change the power output of the source rather than the voltage or reactive power output. This project demonstrated that the ESPSS could modulate the power of the BESS. Encouraged by these findings, SCE decided to test this concept on a synchronous machine to determine if this technology could dampen the inter-area oscillation of the WSCC.

SCE, assisted by a subcontractor, began to conduct system simulation studies and designed and built two Energy Source Stabilizers (ESS) for installation at the Alamitos generating station. A previous report documents the simulation studies and analysis that was used to develop the structure of the governor controller and select the settings for the Alamitos station [1]. The details of this report are outside the scope of this project.

ESS combines an Excitation Power System Stabilizer (EPSS) and a Governor Power System Stabilizer (GPSS). The EPSS functions through the generator excitation system whereas the GPSS works on the governor system and modulates the real power output of the generator EPSS is an existing technology whereas GPSS is a new concept. Figure 1 is a block diagram of EPSS and Figure 2 is a block diagram of GPSS. GPSS is a non-linear control and is only switched in service when the level of inter-area mode oscillations exceed user-selected thresholds. The presence of inter-area mode oscillation is detected by measuring the deviation of system frequency at the high voltage interconnection of the Alamitos units. The frequency at this point is derived from potential transformer and current transformer inputs at the generator terminals.

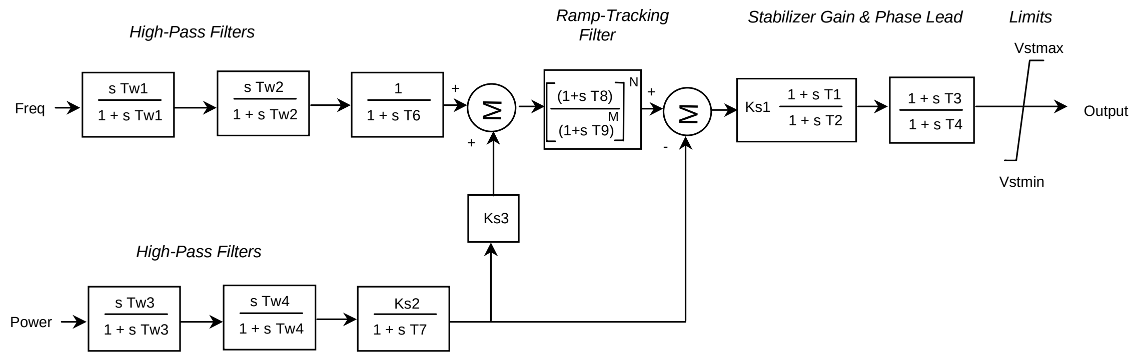

Figure 1. EPSS Block Diagram

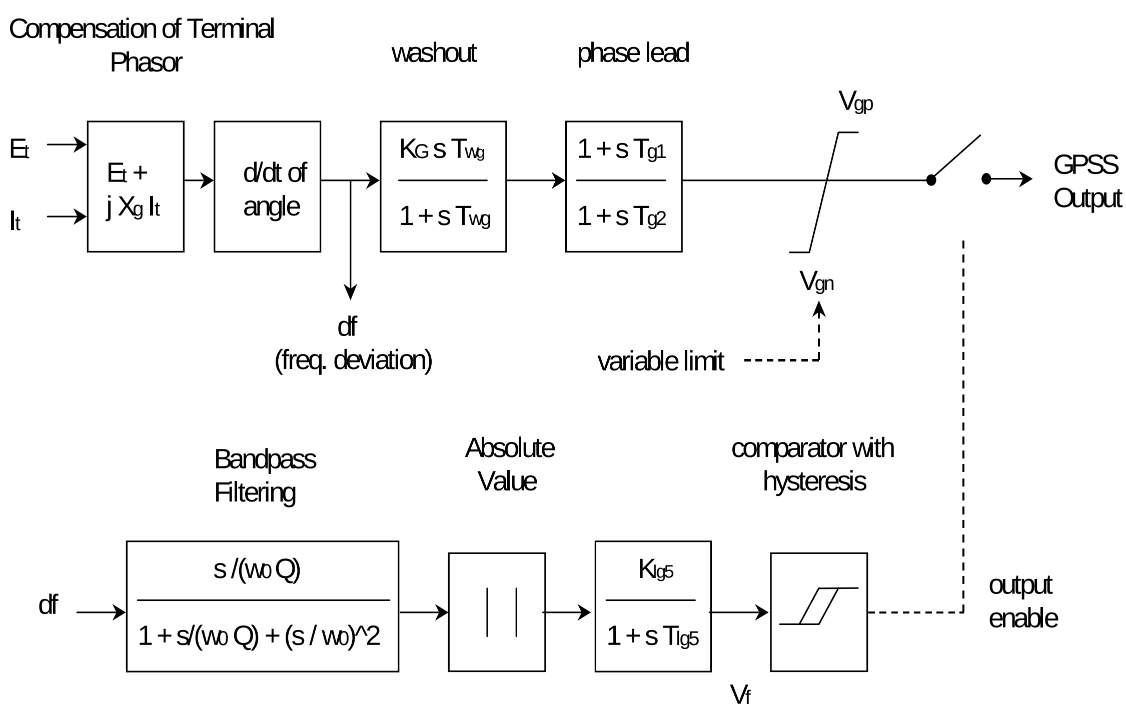

Figure 2. GPSS Block Diagram

The deviation in system frequency is passed through a bandpass filter, which attenuates frequencies outside of the range of 0.2 Hz to 0.8 Hz. The amplitude of the output of this filter is scaled so that it represents the peak magnitude of frequency oscillations at the inter-area mode frequencies. For example, if the generator was participating in an inter-area mode oscillation such that its output frequency varied between 60.05 Hz and 59.95 Hz within a three second interval, the scaled output of the filter would equal 0.05. This level is then compared against a trigger level to determine if the GPSS should be turned on. The final settings were such that the GPSS will only turn on for frequency deviations greater than or equal to 0.05 Hz at the inter-area mode frequencies. Hysteresis is used to ensure that the GPSS is not turned on and off repeatedly for inter-area mode swings which are close to the threshold.

Once the GPSS has been triggered, the output is connected to the control input of the governor valve. The limit on the modulation of unit output power is set for ±10 MW.

The GPSS output uses a fixed output scaling, i.e., 5V = 10 percent valve position change, and the relationship between this voltage, valve movement, and power output is handled within the governor's software logic. Selection of valves, which are modulated, is also performed by the governor. However, the GPSS will not produce an output signal unless the HP generator's output power is above 36 percent of the nameplate rating (100 MW). The GPSS logic will limit the output signal to prevent modulation of the valves to force the power below this minimum level.

1.2. Project Objectives

The project objectives were to:

- Install and test an ESS.
- Monitor the performance of the ESS to improve the reliability of electric transmission and distribution facilities.
- Demonstrate that during Western Systems Coordinating Council (WSCC) system disturbances of inter-area oscillations between 0.3 Hz to 0.7 Hz, the generator real power output can be modulated up to ±10 MW.

1.3. Benefits to California

During certain times of the year, energy imports into California are limited by system stability considerations. One of the major concerns during system stability studies is undamped inter-area oscillations that limit the amount of energy that can be imported into California. After successful demonstration of this project and with future ESS installations in WSCC systems, it may be possible to increase the amount of imports into California on certain paths by 5 to 10 percent.

1.4. Project Expenditures

The California Energy Commission approved project funding of $250,000 under the PIER transition funding program (Figure 3).

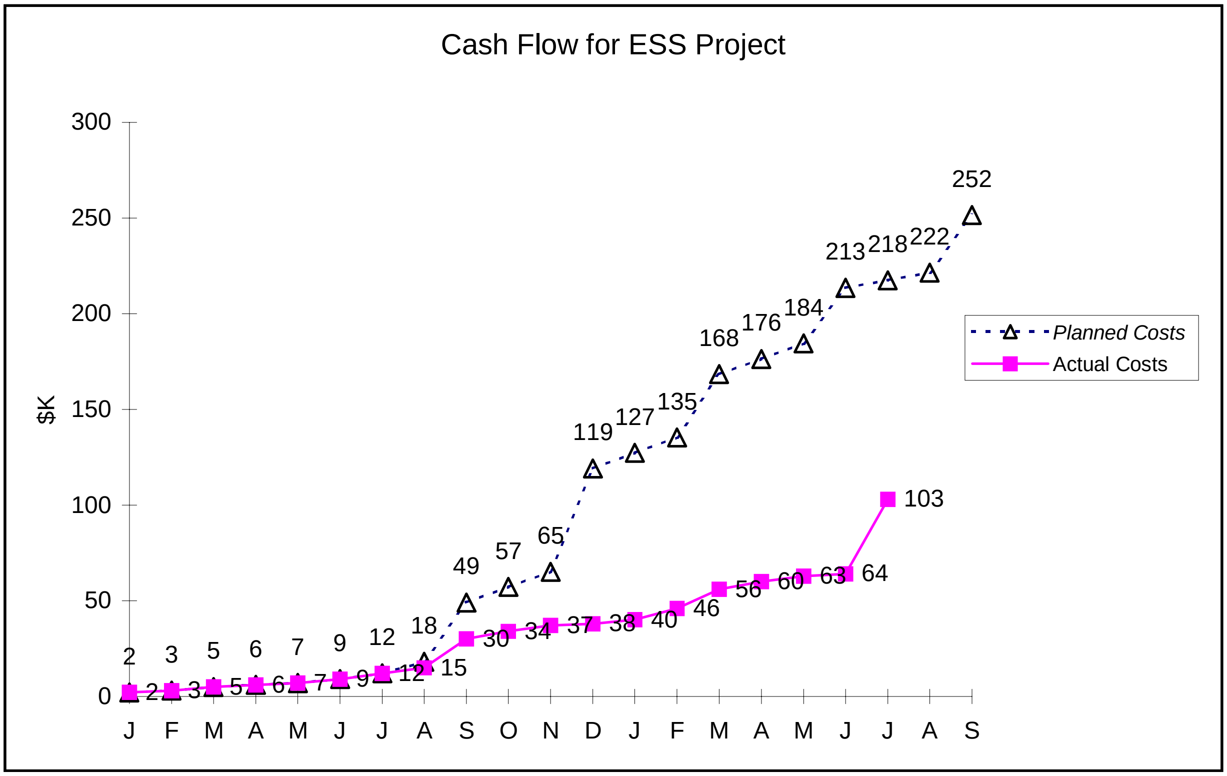

Figure 3. Cash Flow for ESS Project

2.0 Project Approach

The purpose of this project was to demonstrate the ability of ESS systems to supply supplementary damping to inter-area mode oscillations by modulating both the excitation current from the exciter and the mechanical power from the turbine. Modulation of mechanical power was accomplished by a separate function working through the electronic governor steam valve control logic. A low-level electronic signal supplied to the valve controller was used to modulate valve position at the low frequencies associated with the inter-area modes of oscillation. In pursuit of this objective, Southern California Edison installed and tested ESS systems on units 5 and 6 of the Alamitos generation station and monitored their performance from March 1998 to August 1999.

This section is divided into three parts:

- Installation and Testing of Alamitos Unit 6 ESS
- Installation and Testing of Alamitos Unit 5 ESS
- Performance and Monitoring of ESS on Units 5 and 6.

2.1. Installation and Testing of Alamitos Unit 6 ESS

This report contains information on both the site and laboratory tests that were used to confirm that ESS hardware operation matched the design criteria. Additional details as well as sample results are contained in the Appendices.

- Appendix I – Laboratory Test Results
- Appendix II – Test Plan for Site Testing of Alamitos Unit 6
- Appendix III – Selected Site Test Results of Alamitos Unit 6.

2.1.1. Lab Test Results for Unit 6 ESS

The complete description and details of each major step of the laboratory tests performed at the Ontario Hydro Technology Laboratory are provided in Integrated Power System Stabilizer, Technical Services Report, prepared by Ontario Hydro, September 4, 1997. Selected test results are shown in Appendix I. Below are listed the major tests conducted on the ESS hardware and software:

- Frequency Measurement
- Digital Filter Implementation
- GPSS Trigger Algorithm
- Supervision and Limiting
- Real-Time Digital Simulator Tests.

2.1.2. Test Plan of ESS on Unit 6

The description of tests and the dates they were completed is provided in Appendix II. Below are listed the major steps:

- Inspection of Hardware and Wiring
- Software Loading / Verification
- Preparation / Offline Measurements
- Exciter Tuning – LP Unit
- Exciter Tuning – HP Unit
- LP Excitation Stabilizer Measurements
- HP Excitation Stabilizer Measurements
- HP Governor Stabilizer Measurements.

2.1.3. Site Test Results – Alamitos Unit 6

Commissioning tests were performed on unit 6 during two different periods starting on December 15, 1997 and February 09 through12, 1998. Due to unrelated problems with the unit, on-line tests could not be performed. The tests were successfully completed on February 12, 1998, and the stabilizers were left in-service on unit 6. The latest software revision and settings were also installed on the ESS units installed on Alamitos 5.

The results documented in this section are based on the unit 6 tests. Appendix III is a copy of the work performed during both visits. All figures referred to in this section can be found in Appendix III.

2.1.3.1. Excitation System Tuning – LP Unit 6

On the LP unit, several attempts were made to increase the closed-loop Automatic Voltage Regulator (AVR) bandwidth to reduce the stabilizer phase compensation requirements [1]. Tuning had to be performed with the unit on-line since it was not possible to schedule tests with the generator operating on open circuit. During tests of the LP unit, the HP unit excitation was transferred to manual control so that it would not interfere with the evaluation of the closed-loop response of the adjacent unit.

The desired AVR settings that were used in the tuning study for the PSS, are as follows [1]:

- K_A = 400 pu E_{FD} / pu E_{TREF} (resistor R1 on amplifier panel)
- K_F = 0.04 pu E_{TREF} / pu E_{FD} (resistor R7 on damping panel)
- T_F = 0.75 s (resistor R8 on damping panel).

2.1.3.2. EPSS Tuning and Testing – LP Unit 6

Having exhausted all available adjustments on the exciter, the PSS phase compensation was adjusted to provide additional phase lead at frequencies around the local mode of 1.1 Hz.

Appendix III, Figure C3 also includes a plot of the inverted selected phase compensation based on the following transfer function:

$$G_p(s) = \left(\frac{15s}{1+15ss}\right)^2 \left(\frac{1+0.4s}{1+0.02s}\right)^2 \left(\frac{1+0.25s}{1+0.015s}\right)$$

The selected phase lead settings produce a slight over-compensation at frequencies between 0.2 and 1 Hz. This was necessary to produce the required compensation at 1 Hz to maximize the contribution of the EPSS to damping local modes of oscillation.

The selected EPSS structure was the dual-input accelerating power design. This design combines the best properties of both the speed and power stabilizer designs with a crossover filter. At lower frequencies, the EPSS behaves like a speed-based PSS while at higher frequencies it behaves like an integral-of-power PSS. The result is a robust design that attenuates unwanted components in both of the measured signals and permits the use of high gain for maximum contribution to damping. Appendix III, Figure C4 displays the response of the system to the AVR reference step change with the final AVR settings, and with the EPSS gain set to zero. The response is noticeably faster, as seen in the terminal voltage and field voltage traces. As expected, this causes a slight reduction in damping the local mode of oscillation. The compensated frequency signal provides a good approximation to the actual rotor speed as evidenced by the local mode oscillations in this trace.

The EPSS function was placed in service with calculated settings. Even with very low stabilizer gains there was a noticeable improvement in damping the local mode. Appendix III, Figure C5 displays the response with a stabilizer gain of 5.0 pu E_{TREF} / pu ω. The response of the system was tested with gains of up to double the in-service gain without any problem. Even though higher gains could be used, this is not recommended due to the extremely high ratio of phase lead to lag used in this application. Tests were performed with the HP unit's AVR in and out of service, with no difference in the performance of the EPSS on the LP unit.

The stabilizer output limits were set to +10 percent and –5 percent respectively, and the terminal voltage limiter feature was set to operate at 105 percent of rated terminal voltage.

Table 1 lists the final in-service EPSS settings for the LP unit, with reference to the Power System Stabilizer 2A block diagram provided at the beginning of this report.

Table 1. Final In-Service EPSS Settings, Unit 6 LP Alamitos

Variable	Value	Units	Description
T_{W1}	15.00	Seconds	High-pass filter time constant
T_{W2}	15.00	Seconds	High-pass filter time constant
T_{W3}	15.00	Seconds	High-pass filter time constant
T_{W4}	0.0	Seconds	High-pass filter time constant (refer to Note 1)
T_1	0.4	Seconds	Lead compensating time constant
T_2	0.02	Seconds	Lag compensating time constant
T_3	0.4	Seconds	Lead compensating time constant
T_4	0.02	Seconds	Lag compensating time constant
T_{3a}	0.25	Seconds	Lead compensating time constant (refer to Note 3)
T_{4a}	0.015	Seconds	Lag compensating time constant
T_6	0.0	Seconds	Transducer time constant (not applicable)
T_7	15.00	Seconds	refer to note 1
T_8	0.5	Seconds	Mechanical power filter lead time constant
T_9	0.1	Seconds	Mechanical power filter lag time constant
N	1	—	Mechanical power filter order
M	5	—	Mechanical power filter lag order
K_{S1}	5.0	pu $E_{t\text{-}ref}$/ pu $\Delta\omega$	Stabilizer gain
K_{S2}	1.15	—	Refer to Note 1
K_{S3}	1.0	—	Refer to Note 2
V_{STMAX}	0.1	pu $E_{t\text{-}ref}$	Output signal upper limit
V_{STMIN}	-0.05	pu $E_{t\text{-}ref}$	Output signal lower limit
X_Q	0.6	pu Z	Frequency compensation setting

Notes:

1. In the accelerating-power configuration ($\Delta P\omega$) the block $K_{S2}/(1 + sT_7)$ represents the combination of a high-pass filter and the integrator stage. Based on this, the coefficients are calculated as follows: $K_{S2} = T_W/2H$ and $T_7 = T_W$
2. In the (P) configuration, the gain of the electrical power summing input to the low-pass filter, K_{S3}, must be unity to produce an integral-of-mechanical power signal at the output of the summer.
3. The additional stage of lead-lag compensation is not explicitly included in the IEEE PSS2A representation, but is available in many simulation programs.

2.1.3.3. Excitation System Tuning – HP Unit 6

The process described for the LP unit was repeated on the HP unit's excitation system. The settings of the three variable resistors were adjusted to the same values that were used on the LP system:

- R7 (damping gain) from 38 Ω to 15 Ω
- R8 (damping time constant) from 25 Ω to 10 Ω
- R1 (forward gain) from 114 Ω to 26 Ω.

During tests of the HP unit, the LP unit excitation was transferred to manual control. The response is similar to the as-found response for the LP unit, and is significantly less responsive than predicted based on the data provided by Westinghouse. No reason could be found for the difference in response, and the new settings had to be used as the basis for the tuning of the EPSS function on the HP unit.

2.1.3.4. EPSS Tuning and Testing – HP Unit 6

Appendix III, Figure C7 displays results of a closed-loop AVR transfer function measurement, performed at loads of 227 MW, 3 MVAr and 19.5 kV. The phase lag is over 200 degrees at 1 Hz and much higher at 2 Hz, the frequency of the local electromechanical mode for this unit.

$$G_p(s) = \left(\frac{15s}{1+15ss}\right)^2 \left(\frac{1+0.4s}{1+0.02s}\right)^2 \left(\frac{1+0.3s}{1+0.015s}\right)$$

Based on Appendix III, Figure C6 it can be seen that the introduction of changes through the voltage regulator does not initiate significant electromechanical oscillations on the unit. Based on this it was anticipated that the EPSS would be ineffective at local-mode frequencies. The EPSS was placed in service and the gain gradually increased. Damping of the 2 Hz mode of oscillation began to decrease as the gain was increased, and sustained oscillations were obtained for gains above 4 pu E_{tref} / pu ω. The phase compensation was adjusted to focus on the higher frequencies, without success. Larger spreads between the lead and lag time constants were ruled out since they would result in significant overcompensation of the low-frequency inter-area modes, which are the primary concern at this location.

Based on these tests, the EPSS was re-configured to operate as a terminal frequency-based stabilizer with compensation settings equal to those in-service with the previous stabilizer. The frequency input does not contain significant components of the local-mode oscillations and can therefore be applied in situations where it is not possible to provide adequate amounts of phase lead at the higher frequencies.

$$G_p(s) = \frac{10s}{1+10ss} \left(\frac{1+1.0s}{1+0.1s}\right)^2$$

The frequency compensation was set equal to zero, to attenuate any components of the local mode at the input to the stabilizer. In this way the phase compensation will be of little concern at frequencies above the inter-area modes. The stabilizer was left in service with these settings and a gain of 2.0 pu E_{tref} / pu f. Appendix III, Figure C8 displays the first half of a step response test with the PSS in-service at its final gain. The test did not excite the local mode, which is very well damped. As expected the PSS output signal consists of some high-frequency content and almost no component of the local mode. Power spectrum measurements of the calculated speed, power and EPSS output signal confirmed that the torsional (27.9 Hz) and local mode (2.2 Hz) components are unaffected by the EPSS at this gain level. When the EPSS gain was increased above 5.0, the damping of the local mode began to drop quickly, prompting the use of the lower gain. With the final settings, the EPSS is appropriately compensated for the inter-area modes and should supplement damping at these frequencies.

The tests were repeated on the HP unit, with the LP AVR and Power System Stabilizer in-service. There was no evidence of undesirable interactions between the units.

Table 2 shows settings for the EPSS on the HP unit, which uses the industry-standard Power System Stabilizer 1A model.

Table 2. Final In-Service EPSS Settings, Unit 6 HP Alamitos

Variable	Value	Units	Description
T_5	10.00	Seconds	High-pass filter time constant
T_1	1.0	Seconds	Lead compensating time constant
T_2	0.1	Seconds	Lag compensating time constant
T_3	1.0	Seconds	Lead compensating time constant
T_4	0.1	Seconds	Lag compensating time constant
T_6	0.01	Seconds	Transducer time constant
A_1	0.0	—	Torsional filter coefficients
A_2	0.0	—	Torsional filter coefficients
K_S	2.0	pu $E_{t\text{-}ref}$/ pu Δf	Stabilizer gain
V_{STMAX}	0.1	pu $E_{t\text{-}ref}$	Output signal upper limit
V_{STMIN}	-0.05	pu $E_{t\text{-}ref}$	Output signal lower limit
X_Q	0.0	pu Z	Frequency compensation setting

2.1.3.5. Unit 6 GPSS Testing

Two distinct portions of the GPSS require consideration: the triggering function and the main signal path. As an initial check, the internal quantities used within the trigger algorithm were monitored for ambient conditions. Appendix III, Figure C9 displays one of the captured records. The compensated frequency signal, which represents the frequency of the high-voltage bus, contains negligible content at the local-mode frequency. As expected the bandpass filter attenuates both the high and low frequency content, leaving only components with frequency in the target band. For ambient conditions, the trigger signal did not increase above a few mHz.

Once the GPSS has been triggered, the output is connected to the governor's valve control input. The unit was switched from sequential valve control to single valve control. For the test load level, the HP unit was at 239 MW and the total load was at 420 MW. This resulted in valve 6, which was selected for modulation by the GPSS, being open to 30 percent of full opening. In this region, the response of steam flow versus opening is approximately linear. A step change in the valve reference was applied and the calibration adjusted to obtain a correlation between the applied voltage and final power change (143 V / pu MVA on HP base). A 3.5 percent step response represents approximately a 10 MW demand change, as shown in Appendix III, Figure C10. The initial response to the step is very rapid, as expected, followed by a slow secondary response associated with the long reheater time constant.

The limit on the modulation of unit output power was set for ±10 MW. The GPSS was also configured to not produce an output unless the HP generator's output power is above 100 MW, 36 percent of the nameplate rating. The GPSS logic will limit the output signal to prevent modulation of the valves to force the power below this minimum level.

A transfer function was performed to confirm the required phase compensation for the GPSS function. Appendix III, Figure C11 displays the measured results. There is relatively little phase lag introduced between in the modulation of output power via the valve controller on this governor. The phase compensation settings for the GPSS were modified slightly from the original study values [1], to avoid over-compensating. The new transfer function is:

$$G_{GPSS}(s) = \left(\frac{s5}{1+s5}\right)\left(\frac{1+s0.4}{1+s0.08}\right)\left(\frac{1}{1+s0.02}\right)$$

The selected compensation (inverted) is also plotted in Appendix III on Figure C11 for comparison. The difference between the selected and required phase compensation is within 10 degrees for frequencies between 0.3 and 0.7 Hz, the two dominant inter-area modes.

Once the phase compensation had been selected, the signals in the main GPSS path were monitored in both the time and frequency domain to confirm that they did not contain significant content at higher frequencies. Power spectrum measurements of the compensated GPSS frequency did not reveal any significant content at the local mode frequency (2 Hz) or at the first torsional mode frequency (28 Hz).

The internal test source was used to add a 0.3 Hz sinusoidal component to the calculated GPSS terminal frequency. Once this signal is added at the input to the GPSS, it is used by all subsequent algorithms (triggering and main signal path) as if it were part of the actual signal. This provides an on-line verification of the triggering algorithm and the valve modulation through the GPSS compensation function. During the initial tests, a problem was discovered with the test signal generation. The bug was fixed and a new version of the application was created, tested and loaded on the IPSS unit.

Appendix III, Figure C12 displays results of a test in which a sinusoidal test input was added to the GPSS frequency input. The plotted compensated frequency in Appendix III, Figure C12, is the calculated value before the test signal is applied (i.e., it reflects the modulation of the frequency caused by the GPSS operation). The test signal consisted of a peak frequency change of 30 mHz at a modulating frequency of 0.3 Hz. The trigger level was set at 20 mHz, and the data record confirms correct triggering at this level. The frequency modulation (30 mHz = 0.0005 pu) produces an output modulation of approximately 1.2 percent peak, with a GPSS gain of –20 pu V_{gref} / pu f, due to the effect of the phase lead. The resulting change in active power is 3 MW peak, or 1.1 percent peak on the HP generator base. This confirms the ability of the GPSS to modulate the valves and produce desired changes in active power for realistic operating settings. Various modulation levels were tested with similar results.

The GPSS gain was increased to –40 pu, and the modulating signal was increased to 60 mHz peak. This forced the GPSS against its output limits in both directions (±0.036 pu V_{gref}) as shown in Appendix III, Figure C13. This produced an output modulation of just under 7 MW peak, compared with the maximum limit of 10 MW. This is consistent with the portion of the power that is derived from the HP turbine. Subsequent changes from the Intermediate Pressure and LP are delayed sufficiently by the reheater and other time constants that they will not contribute significantly at these modulating frequencies. It was decided to leave the GPSS output calibration as a function of the total output power available for a given valve position change. This was used in the original studies [1] and during the initial evaluation period.

The GPSS was triggered for continuous conditions by lowering the GPSS trigger to a very low level. Power spectrum measurements of a number of quantities, including compensated frequency, power and the GPSS output signal, confirmed that high-frequency components are not affected by the operation of the GPSS.

The original studies [1] indicated that the damping improvements from the EPSS and GPSS were additive, and that they could both be left in-service in the presence of high levels of inter-area modes. Since the EPSS design was changed on the HP, it was decided that the IPSS would be operated in exclusive mode, i.e., the EPSS is turned off when the GPSS is triggered. This mode of operation was confirmed, as shown in Appendix III, Figure C14.

Table 3 shows settings for the unit, left in service after the GPSS gain was reduced.

Table 3. Final In-Service GPSS Settings, Unit 6 HP Alamitos

Variable	Value	Units	Description
T_{wg}	5.00	Seconds	High-pass filter time constant
T_{g1}	0.4	Seconds	Lead compensating time constant
T_{g2}	0.08	Seconds	Lag compensating time constant
T_{g3}	0.0	Seconds	Lead compensating time constant
T_{g4}	0.02	Seconds	Lag compensating time constant
K_G	-10.0	pu $V_{g\text{-}ref}$/ pu Δf	Stabilizer gain
V_{GP}	0.036	pu $_{Vg\text{-}ref}$	Output signal upper limit
V_{GN}	-0.036	pu $V_{g\text{-}ref}$	Output signal lower limit
X_G	-0.13	pu Z	Frequency compensation setting
F_0	0.5	Hz	Bandpass center frequency
Q	0.707	—	Bandpass Q-factor
K_{LG5}	1.0	—	Trigger LP filter gain
T_{LG5}	1.0	S	Trigger LP filter time constant
F_{on}	0.05	Hz	GPSS trigger turn-on level
F_{hyst}	25	%	GPSS trigger hysteresis

The gain on the GPSS can be increased to the final recommended level of –40.0 pu V_{gref} / pu f, once its performance has been evaluated during a period of normal operation.

The EPSS turn-on level is set for 42 MW (15 percent of rated MVA on the HP) while the GPSS turn-on level corresponds to the minimum operating power level of 100 MW (36 percent).

2.1.3.6. Conclusions of Unit 6 Testing

Tests have been performed which successfully confirm the correct operation of both the EPSS and IPSS units installed on Alamitos unit 6. Most of the tests were performed at load levels between 350 and 400 MW to accommodate system requirements.

On the LP unit, several attempts were made to increase the closed-loop automatic voltage regulator (AVR) bandwidth to reduce the stabilizer phase compensation requirements. The final AVR settings did not exactly match the performance predicted from Westinghouse data for the unit, and the stabilizer settings were adjusted to compensate. The EPSS was placed in service and tests were performed to confirm correct operation. The PSS was extremely effective in damping out local mode oscillations (plant – system). Final settings were selected to provide supplementary damping at both the inter-area and local modes of oscillation.

Similar tuning of the AVR on the HP unit did not produce comparable results. The closed-loop bandwidth was considerably lower, despite the use of the highest available gain and optimum damping feedback. An attempt was made to commission the PSS with extreme phase compensation settings, but this proved unsuccessful. The structure of the EPSS was adjusted to match the previous design (i.e., single-input frequency PSS) and the settings were adjusted to provide good phase compensation at the inter-area modes. The PSS was placed into service and tested with these settings. The HP unit exhibits good damping of the local mode of oscillation, which is above 2 Hz, and the excitation system does not significantly increase or decrease the damping. With the final settings and structure, the EPSS on the HP unit will provide supplementary damping of the inter-area modes without significantly affecting the damping of the local mode.

Following the commissioning of the EPSS function on the HP unit, the GPSS unit was tested and placed in service. The tests consisted of both time and frequency domain measurements, in which a governor valve was modulated at low frequencies. The required GPSS compensation was measured and found to be slightly lower than the calculated requirement. The GPSS phase compensation was adjusted and the GPSS placed in service. Long-term monitoring of the GPSS signals, including repeated torsional measurements, confirmed that the GPSS calculation algorithms were performing as expected. A test signal was added to the frequency input signal to simulate an inter-area mode oscillation at 0.3 Hz. The GPSS triggered as expected and the valves were modulated to produce the desired active power changes. This test was repeated several times with different modulation levels up to the active power limits.

The EPSS on the LP unit and the IPSS on the HP unit were left in-service, and the data recorder auto-trigger feature was configured to collect data on any upcoming system events. Modems were supplied for communication with the units for remote access to data records.

2.2. Installation and Testing of Alamitos Unit 5 ESS

This section contains information about installation and testing of ESS on Unit 5. The details of the test plan and site results are provided in Appendices IV and V. The laboratory testing results of Unit 6 ESS were used for Unit 5 ESS because both Energy Source Stabilizers are identical.

- Appendix IV – Test Plan for Site Testing of Alamitos Unit 5
- Appendix V – Selected Site Test Results of Alamitos Unit 5.

2.2.1. Test Plan of ESS on Unit 5

The description of tests and the dates they were completed is provided in Appendix IV. Below are listed the major steps:

- Inspection of Hardware and Wiring
- Software Loading / Verification
- Preparation / Offline Measurements
- Exciter Tuning –LP Unit
- Exciter Tuning –HP Unit
- LP Excitation Stabilizer Measurements
- HP Excitation Stabilizer Measurements
- HP Governor Stabilizer Measurements.

2.2.2. Site Test Results – Alamitos Unit 5

Commissioning tests were performed on unit 5 during two different periods starting on March 26, 1999 and May 18, 1999. Due to voltage regulator problems with the unit, on-line tests could not be completed during the first visit. The voltage regulator problems are documented in the Engineering Report, prepared by Edison ESI, March 26, 1999. The tests were successfully completed on May 19, 1999, and the stabilizers were left in-service on unit 5. Appendix V provides more details about the site test results on Alamitos unit 5. All the figures referred to in this section can be found in Appendix V.

2.2.2.1. Excitation System Tuning – LP Unit 5

Based on the results of the unit 6 excitation system tuning, the unit 5 LP was adjusted to provide a similar response. During tests of the LP unit, the HP unit excitation was transferred to manual control, so that it would not interfere with the evaluation of the closed-loop response of the adjacent unit.

Appendix V, Figure B1 displays the on-line step response for the LP voltage regulator, obtained with the unit operating at 185 MW, 34 MVAr and 19.88 kV. The closed-loop voltage regulator response is well-damped but slow. The local-mode oscillations are visible in the power trace similar to what was seen on Unit 6 LP. Appendix V, Figure B2 shows the frequency response of the uncompensated generator loop. These are clear examples of why a compensated frequency, or measured speed signal, must be used in applications where damping of local mode oscillations is required.

2.2.2.2. EPSS Tuning and Testing – LP Unit 5

The PSS phase compensation was adjusted to provide additional phase lead at frequencies around the local mode (1.1 Hz). Appendix V, Figure B3 is the frequency response of the compensated EPSS settings based on the following transfer function:

$$G_p(s) = \left(\frac{15s}{1+15ss}\right)^2 \left(\frac{1+0.4s}{1+0.02s}\right)^2 \left(\frac{1+0.25s}{1+0.015s}\right)$$

The selected phase lead settings produce a slight over-compensation at frequencies between 0.2 and 1 Hz. This was necessary to produce the required compensation at 1 Hz, in order to maximize the contribution of the EPSS to damping of the local mode of oscillation.

The selected EPSS structure was the dual-input accelerating power design. This design combines the best properties of both the speed and power stabilizer designs using a crossover filter; at lower frequencies the EPSS behaves like a speed-based PSS while at higher frequencies it behaves like an integral-of-power PSS. The result is a robust design that attenuates unwanted components in both of the measured signals and permits the use of high gain for maximum contribution to damping.

Appendix V, Figure B4 displays the frequency response of the compensated generator loop. Appendix V, Figure B5 displays the response of the system to the AVR reference step change with the final AVR settings, and with the EPSS gain set to zero.

The EPSS function was placed in service with the calculated settings. Even with very low stabilizer gains there was a noticeable improvement in the damping of the local mode. Appendix V, Figure B6 displays the response with a stabilizer gain of 5.0 pu E_{tref} / pu . The response of the system was tested with gains of up to double the in-service gain without any problem. Even though higher gains could be used, this is not recommended due to the extremely high ratio of phase lead to lag used in this application. Tests were performed with the HP unit's AVR in and out of service, with no difference in the performance of the EPSS on the LP unit.

The stabilizer output limits were set to +10 percent and –5 percent respectively, and the terminal voltage limiter feature was set to operate at 105 percent of rated terminal voltage.

Table 4 lists the final in-service EPSS settings for the LP unit, with reference to the PSS2A block diagram provided at the beginning of this report.

Table 4. Final In-Service EPSS Settings, Unit 5 LP Alamitos

Variable	Value	Units	Description
T_{W1}	15.00	Seconds	High-pass filter time constant
T_{W2}	15.00	Seconds	High-pass filter time constant
T_{W3}	15.00	Seconds	High-pass filter time constant
T_{W4}	0.0	Seconds	High-pass filter time constant (refer to Note 1)
T_1	0.4	Seconds	Lead compensating time constant
T_2	0.02	Seconds	Lag compensating time constant
T_3	0.4	Seconds	Lead compensating time constant
T_4	0.02	Seconds	Lag compensating time constant
T_{3a}	0.25	Seconds	Lead compensating time constant (refer to Note 3)
T_{4a}	0.015	Seconds	Lag compensating time constant
T_6	0.0	Seconds	Transducer time constant (not applicable)
T_7	15.00	Seconds	Refer to Note 1
T_8	0.5	Seconds	Mechanical power filter lead time constant
T_9	0.1	Seconds	Mechanical power filter lag time constant
N	1	—	Mechanical power filter order
M	5	—	Mechanical power filter lag order
K_{S1}	5.0	pu $E_{t\text{-}ref}$/ pu	Stabilizer gain
K_{S2}	1.15	—	Refer to Note 1
K_{S3}	1.0	—	Refer to Note 2
V_{STMAX}	0.1	pu $E_{t\text{-}ref}$	Output signal upper limit
V_{STMIN}	-0.05	pu $E_{t\text{-}ref}$	Output signal lower limit
XQ	0.6	pu Z	Frequency compensation setting

Notes:

1. In the accelerating-power configuration (P) the block $K_{S2}/(1 + sT_7)$ represents the combination of a high-pass filter and the integrator stage. Based on this, the coefficients are calculated as follows: $K_{S2} = T_W/2H$ and $T_7 = T_W$
2. In the (P) configuration, the gain of the electrical power summing input to the low-pass filter, K_{S3}, must be unity to produce an integral-of-mechanical power signal at the output of the summer.
3. The additional stage of lead-lag compensation is not explicitly included in the IEEE PSS2A representation, but is available in many simulation programs.

2.2.2.3. Excitation System Tuning – HP Unit 5

The process described for the LP unit was repeated on the HP unit's excitation system. Based on the results of the unit 6 excitation system tuning, the unit 5 HP was adjusted to provide a similar response. During tests of the HP unit, the LP unit excitation was transferred to manual control, so that it would not interfere with the evaluation of the closed-loop response of the adjacent unit. Appendix V, Figure B7 displays the closed loop AVR response to a 1 percent step change in the reference signal.

2.2.2.4. EPSS Tuning and Testing – HP Unit 5

Appendix V, Figure B8 displays the results of a closed-loop AVR transfer function measurement, performed at a load of 196 MW, 44 MVAr and 20.01 kV. The phase lag is over 200 degrees at 1 Hz and much higher at 2 Hz, the frequency of the local electromechanical mode for this unit.

Based on Appendix V, Figure B7 it can be seen that the introduction of changes through the voltage regulator does not initiate significant electromechanical oscillations on the unit. Just as in the case of Unit 6 HP, it was anticipated that the EPSS would be ineffective at local-mode frequencies. The EPSS was configured to operate as a terminal frequency-based stabilizer with compensation settings equal to those in-service with the previous stabilizer. The frequency input does not contain significant components of the local-mode oscillations and can therefore be applied in situations where it is not possible to provide adequate amounts of phase lead at the higher frequencies. Appendix V, Figure B9 plots the selected compensation based on the following transfer function:

$$G_p(s) = \frac{10s}{1+10ss}\left(\frac{1+10s}{1+0.1s}\right)^2$$

The frequency compensation was set equal to zero, to attenuate any components of the local mode at the input to the stabilizer. In this way the phase compensation will be of little concern at frequencies above the inter-area modes. Appendix V, Figure B10 is the result of the closed loop AVR transfer function for the compensated generator loop. Appendix V, Figure B11 displays the response of the system to a 1 percent step change in reference voltage with the gain set at 0. Appendix V, Figure B12 is a step response with the gain set at 2.0 pu E_{tref} / pu f. The test did not excite the local mode, which is very well damped. As expected the PSS output signal consists of some high-frequency content and almost no component of the local mode. Power spectrum measurements of the calculated speed, power and EPSS output signal confirmed that the torsional (27.9 Hz) and local mode (2.2 Hz) components are unaffected by the EPSS at this gain level. With the final settings, the EPSS is appropriately compensated for the inter-area modes and should supplement damping at these frequencies.

The tests were repeated on the HP unit, with the LP AVR and PSS in-service. There was no evidence of undesirable interactions between the units.

The EPSS on the HP unit can be represented using the industry-standard PSS1A model, with the settings of Table 5.

Table 5. Final In-Service EPSS Settings, Unit 5 HP Alamitos

Variable	Value	Units	Description
T_5	10.00	Seconds	High-pass filter time constant
T_1	1.0	Seconds	Lead compensating time constant
T_2	0.1	Seconds	Lag compensating time constant
T_3	1.0	Seconds	Lead compensating time constant
T_4	0.1	Seconds	Lag compensating time constant
T_6	0.01	Seconds	Transducer time constant
A_1	0.0	—	Torsional filter coefficients
A_2	0.0	—	Torsional filter coefficients
K_S	2.0	pu $E_{t\text{-}ref}$/pu f	Stabilizer gain
V_{STMAX}	0.1	pu $E_{t\text{-}ref}$	Output signal upper limit
V_{STMIN}	-0.05	pu $E_{t\text{-}ref}$	Output signal lower limit
X_Q	0.0	pu Z	Frequency compensation setting

2.2.2.5. Unit 5 GPSS Testing

There are two distinct portions of the GPSS that require consideration: the triggering function and the main signal path. The Unit 5 GPSS trigger scheme was tuned to match the results obtained during the unit 6 commissioning. The compensated frequency signal (representing the frequency of the high-voltage bus) contains negligible content at the local-mode frequency and the bandpass filter attenuates both the high and low frequency content, leaving only components with frequency in the target band.

Once the GPSS has been triggered, the output will be connected to the governor's valve control input. A signal was applied at the GPSS output to verify the governor valves could be modulated as seen in Appendix V, Figure B13.

The limit on the modulation of unit output power was set for ±10 MW. The GPSS was also configured to not produce an output unless the HP generator's output power is above 100 MW, 36 percent of the nameplate rating. The GPSS logic will limit the output signal to prevent modulation of the valves to force the power below this minimum level.

The phase compensation settings for the GPSS were based on the following transfer function and match those found on unit 6.

$$G_{GPPS}(s) = \left(\frac{s5}{1+s5}\right)\left(\frac{1+s0.4}{1+s0.08}\right)\left(\frac{1}{1+s0.02}\right)$$

The internal test source was used to add a 0.3 Hz sinusoidal component to the calculated GPSS terminal frequency. Once this signal is added at the input to the GPSS, it is used by all subsequent algorithms (triggering and main signal path) as if it were part of the actual signal. This provides an on-line verification of the triggering algorithm and the valve modulation through the GPSS compensation function. During the initial tests, a problem was discovered with the GPSS output function. With the IPSS set for Solo mode operation, anytime the GPSS triggered, the EPSS would be disabled. This in turn disabled the output of the D/A card and no GPSS signal was passed. By setting the IPSS for Dual mode, the EPSS was left in service and the GPSS signal was passed along.

Appendix V, Figure B14 displays the results of a test in which a sinusoidal test input was added to the GPSS frequency input. The plotted compensated frequency in Appendix V, Figure B14, is the calculated value before the test signal is applied (i.e., it reflects the modulation of the frequency caused by the GPSS operation). The test signal consisted of a peak frequency change of 15 mHz at a modulating frequency of 0.3 Hz. The trigger level was set at 10 mHz, and the data record confirms correct triggering at this level. The frequency modulation (15 mHz = 0.00025 pu) produces an output modulation of approximately 0.6 percent peak, with a GPSS gain of –20 pu Vgref/pu f, due to the effect of the phase lead. The resulting change in active power is approximately 1.25 MW peak, or 0.45 percent peak on the HP generator base. This confirms the ability of the GPSS to modulate the valves and produce the desired changes in active power for realistic operating settings.

Following these tests the GPSS gain was reduced and the unit was left in-service. Table 6 settings were maintained, with reference to the GPSS block diagram.

Table 6. Final In-Service GPSS Settings, Unit 5 HP Alamitos

Variable	Value	Units	Description
T_{wg}	5.00	Seconds	High-pass filter time constant
T_{g1}	0.4	Seconds	Lead compensating time constant
T_{g2}	0.08	Seconds	Lag compensating time constant
T_{g3}	0.0	Seconds	Lead compensating time constant
T_{g4}	0.02	Seconds	Lag compensating time constant
K_G	–10.0	Pu $V_{g\text{-}ref}$/pu f	Stabilizer gain
V_{GP}	0.036	Pu $V_{g\text{-}ref}$	Output signal upper limit
V_{GN}	–0.036	Pu $V_{g\text{-}ref}$	Output signal lower limit
X_G	–0.13	Pu Z	Frequency compensation setting
F_0	0.5	Hz	Bandpass center frequency
Q	0.707	—	Bandpass Q-factor
K_{LG5}	1.0	—	Trigger LP filter gain
T_{LG5}	1.0	S	Trigger LP filter time constant
F_{on}	0.05	Hz	GPSS trigger turn-on level
F_{hyst}	25	%	GPSS trigger hysteresis

The gain on the GPSS can be increased to the final recommended level of –40.0 pu V_{gref}/pu f, once its performance has been evaluated during a period of normal operation. The EPSS turn-on level is set for 42 MW (15 percent of rated MVA on the HP) while the GPSS turn-on level corresponds to the minimum operating power level of 100 MW (36 percent).

2.3. Performance Monitoring of ESS on Units 5 and 6

This section discusses the manner ESS performance based data was recorded and stored. ESS performance data was captured by the on-board data logger and downloaded to a laptop computer in ASCII format. This data was then imported into an MS EXCEL spreadsheet and the data converted from per unit to its appropriate full value units, i.e., MW, Generator kV, Volts DC, or frequency (Hz). The data was then grouped and plotted on two different charts allowing for the difference in scale. The data is contained in Appendices VI through X.

At the end of each reporting period, the data was analyzed to determine if the data recorder captured any data. If no data was captured, then the auto trigger values of the data logger were modified. Table 7 summarizes the auto trigger values in each of the reports.

Table 7. Auto Trigger Values of the Data Logger

Report	EPSS Output	Number of Half Cycle to DELAY	GPSS Trigger Set Point (Hz)
1	0.03	5	0.03
2	0.02	20	0.02
3	0.02	20	0.02
4	0.02	20	0.005
5	0.02	20	0.005

The following can be concluded from these reports:

- The EPSS portions of the IPSS for both the HP and LP generators have triggered several data records.
- The governor power system stabilizer (GPSS) portion of the IPSS on the HP generator has also been triggered and operated.

For the GPSS on unit 5 and 6 to operate, ALL of the following conditions need to be satisfied:

- There is a disturbance on the system
- Units 5 or 6 is operating and the HP output is more than 100 MW
- The frequency deviation due to the disturbance is more than 0.05 Hz
- The change in frequency is oscillating within a period of approximately 3 seconds.

Solo Mode is the output from the IPSS on the HP generator transmitted from either the EPSS or the GPSS; Dual Mode is the output from the IPSS on the HP generator transmitted from both the EPSS and GPSS simultaneously. During commissioning of the unit 5 IPSS, it was discovered that the output D/A converter was switched off whenever the EPSS was disabled. This occurs either from the control room switch, or if the GPSS triggers and the IPSS is selected for SOLO mode operation. Although the GPSS internal signal is still generated, the output is disabled until the trigger signal is removed allowing the D/A to be enabled once again. To avoid this situation, the IPSS on unit 5 was selected to DUAL mode. Although the testing on unit 6 did not indicate a similar problem, unit 6 was switched to DUAL mode operation as a precautionary measure.

3.0 Conclusions and Recommendations

The overall goal was to demonstrate, during a major disturbance in WSCC with inter-area oscillations, that the generator output power can be modulated with ESS to help to decrease the magnitude of inter-area oscillations thereby improving stability of the WSCC system. Specifically: The ESS on Alamitos Units 5 and 6 functioned as designed, modulating the real power output to with in ±10 MW, during WSCC system disturbances of inter-area oscillations between 0.3 Hz to 0.7 Hz.

3.1. Finds from Installation and Testing

3.1.1. Findings from Unit 6 ESS Installation and Testing

The laboratory and field tests confirmed the correct operation of the EPSS and IPSS units. On the LP unit, the EPSS settings were selected to provide supplementary damping at both inter-area and local mode frequencies. On the HP unit, the voltage regulator control loop was too slow to permit proper EPSS operation at the higher local-mode frequencies, and the unit was left in-service with a configuration and settings that will provide supplementary damping at lower inter-area mode frequencies.

On the HP unit, the GPSS was left in-service with a high trigger level (f_{on} = 0.05) and low gain (k_G = -10) These have been adjusted to the values of 0.02 and –20 respectively after an evaluation period.

The progress made leads to a recommendation to complete wiring and modification of Alamitos unit 5. This unit can then be commissioned using the test procedure included in Unit 6 ESS installation report.

3.1.2. Findings from Unit 5 ESS Installation and Testing

The field tests confirmed the correct operation of the EPSS and IPSS units. On the LP unit, the EPSS settings were selected to provide supplementary damping at both inter-area and local mode frequencies. On the HP unit, the voltage regulator control loop was too slow to permit proper EPSS operation at the higher local-mode frequencies, and the unit was left in-service with a configuration and settings that will provide supplementary damping at lower inter-area mode frequencies. These settings are the same as those used on unit 6.

On the HP unit, the GPSS was left in-service with a high trigger level (f_{on} = 0.02) and low gain (k_G = -10). This matches the settings currently in service on unit 6 HP. These will be adjusted to the final values recommended in reference [1], after an evaluation period.

The HP GPSS output would not pass in SOLO mode so the IPSS was left in DUAL operating mode.

The new stabilizer units are equipped with extensive self-checking and data recording features. ETS staff should monitor the operation of the IPSS and EPSS on units 5 and 6 and report/distribute any significant records (e.g., response to significant disturbances or inter-area mode oscillations) obtained from the data recording facility. This data can be helpful in diagnosing a variety of generator control problems and for reporting to regulatory authorities (e.g., WSCC, NERC).

3.2. Potential to Apply the Research Results

All objectives of the research project were satisfied. ESS may be installed at multiple locations throughout WSCC in order to reduce the magnitude of inter-area oscillations during a disturbance. The optimal locations for these ESS installations need to be determined based on WSCC system simulation studies and necessary incentives / policies need to be in place in order for the generator owners to install ESS and provide system reliability.

3.3. Public Interest Benefits if the Research Results are Applied

During certain times of the year, energy imports into California are limited by system stability considerations. One of the major concerns during system stability studies is undamped inter-area oscillations that limit the amount of energy that can be imported into California. After successful demonstration of this project and with future ESS installations in WSCC systems, it may be possible to increase the amount of electricity into California on certain paths 5 to 10 percent.

3.4. Recommendations

Based on the status of the project the following recommendations are made:

- The stabilizer units are equipped with extensive self-checking and data recording features. A process needs to developed in which this data can be made helpful in identifying and diagnosing a variety of generator control problems and for reporting to regulatory authorities with the goal of improving inter-area system reliability.
- Continue to monitor ESS performance to validate the design during various disturbances. Modify ESS design criteria and trigger thresholds, if necessary.
- After successful demonstration in the field, survey the generating facilities in the WSCC to identify candidate generators for ESS installation.
- Conduct WSCC system simulation studies to determine optimal location of the ESS to damp out inter-area oscillations and improve system reliability.

4.0 Glossary

It is important to understand the terminology of the report before getting to the details of the report. For consistency, the following definitions have been used throughout the report:

ESS	Energy Source Stabilizer, is a device that incorporates both the GPSS and EPSS functions to improve power system damping.
IPSS	Integrated Power System Stabilizer, is another name for ESS.
PSS	Power System Stabilizer, is any device that improves the damping of modes of oscillation affecting synchronous machines on an interconnected power system.
DPSS	Digital Power System Stabilizer, is a PSS that is implemented as a digital controller.
EPSS	Excitation Power System Stabilizer, is a PSS that modulates a generator’s output by varying excitation.
GPSS	Governor Power System Stabilizer, is a PSS that modulates a generator’s output by varying the mechanical power output from the turbine.

5.0 References

[1] *Integrated Power System Stabilizer*, *Technical Services Report*, prepared by Ontario Hydro, September 4, 1997.

[2] *IEEE Recommended Practice for Excitation System Models for Power System Stability Studies*, IEEE Standard 421.5-1992, August 1992.

[3] *Engineering Report*, prepared by Edison ESI, March 26, 1999.

Appendix I

IPSS Laboratory Test Results

Appendix II

Site Test Plan Alamitos Unit 6, December 15-20, 1997

Appendix III

Site Commissioning Test Results Alamitos Unit 6, December 15-20, 1997 and February 9-12, 1998

Appendix IV

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Appendix V

Selected Site Test Results of Alamitos Unit 5

Appendix VI

Data Collected for Unit 6 After 3/3/98

Appendix VII

Data Collected for Unit 6 After 1/23/99

Appendix VIII

Data Collected for Unit 6 After 2/26/99

Appendix IX

Data Collected for Unit 6 After 3/25/99

Appendix X

Data Collected For Units 5 and 6 After 5/4/99

Appendix I
IPSS Laboratory Test Results

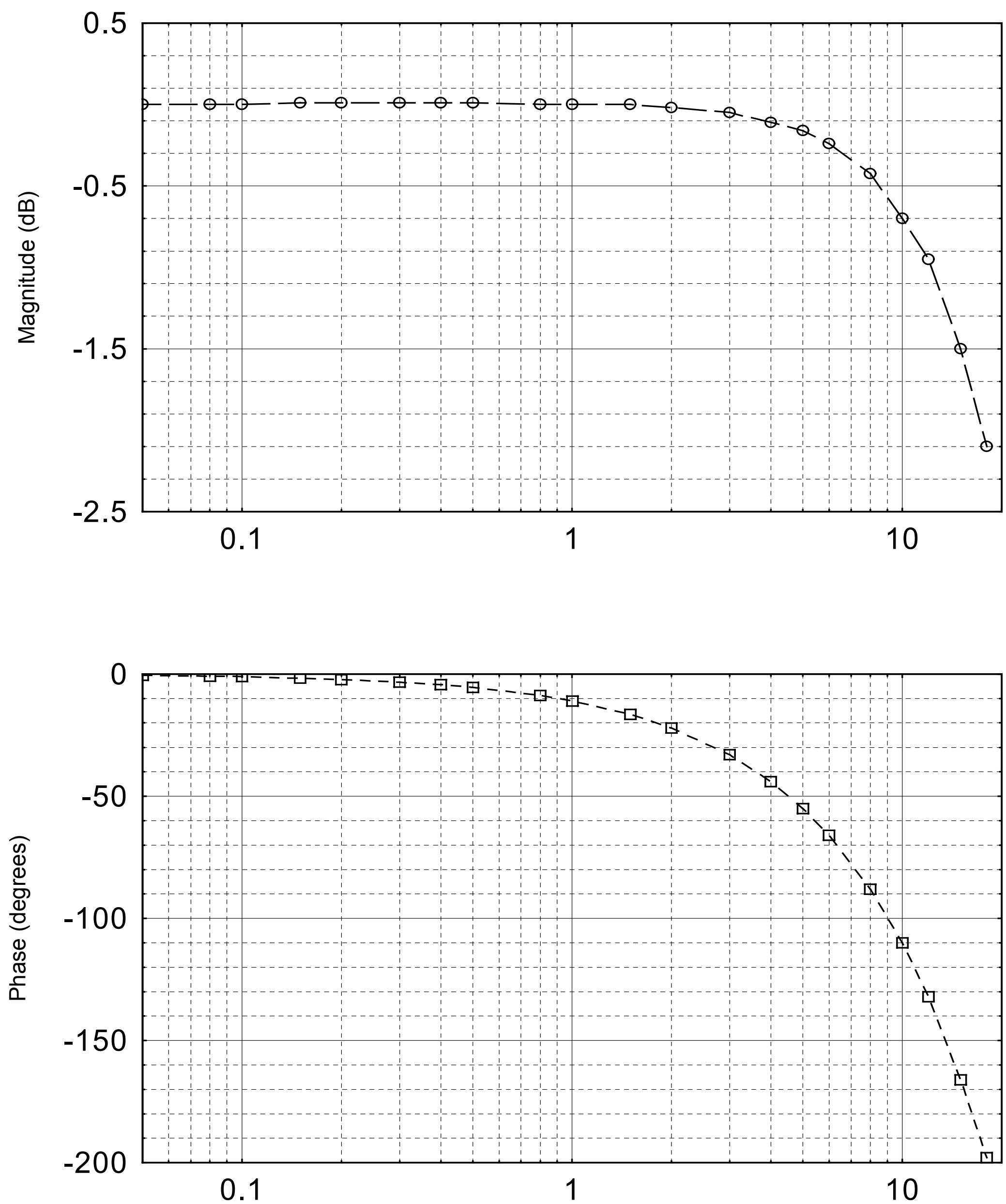


Figure B1. IPSS Lab Measurements Frequency Calculation Transfer Function

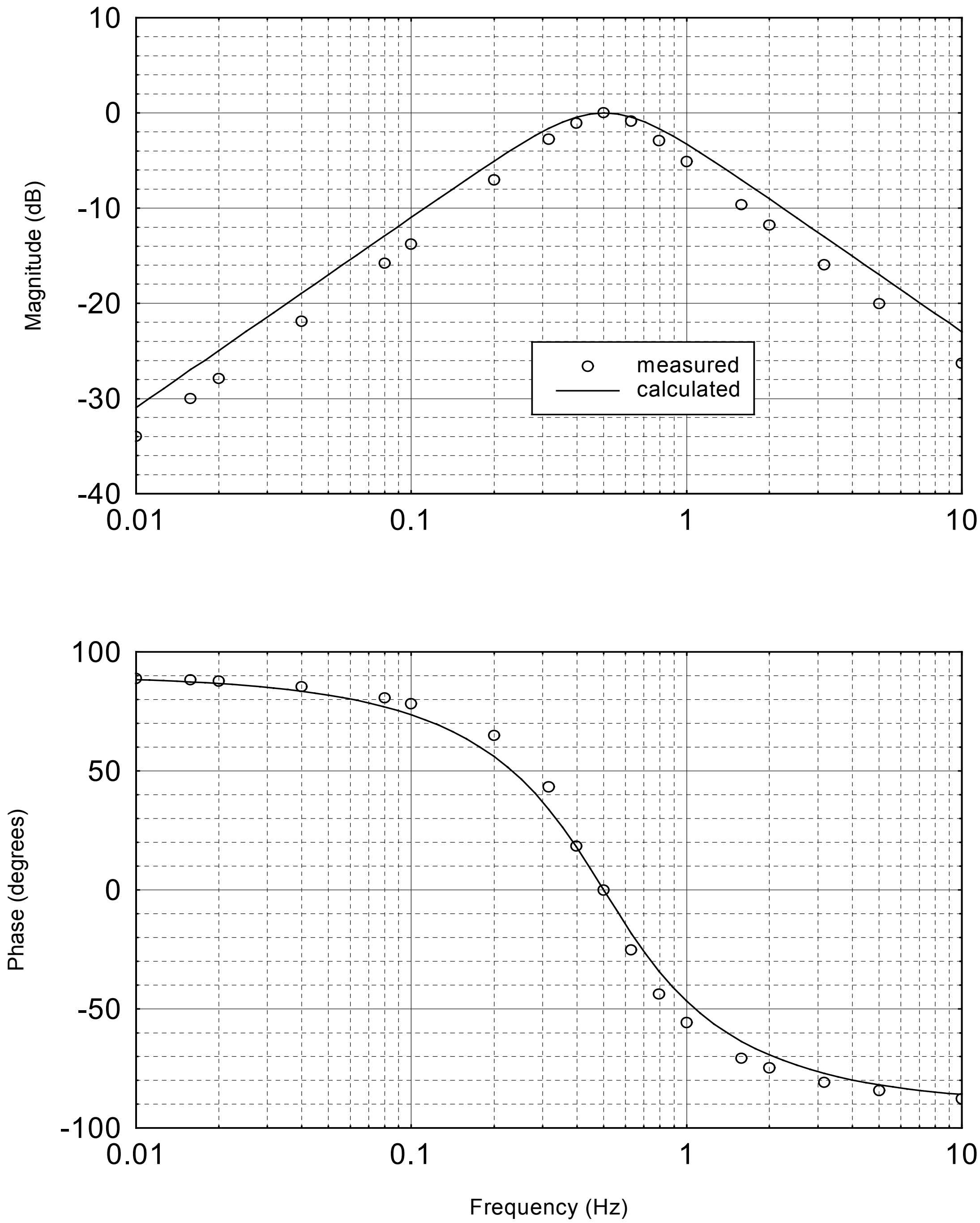


Figure B2. IPSS Lab Measurements Bandpass Filter Transfer Function

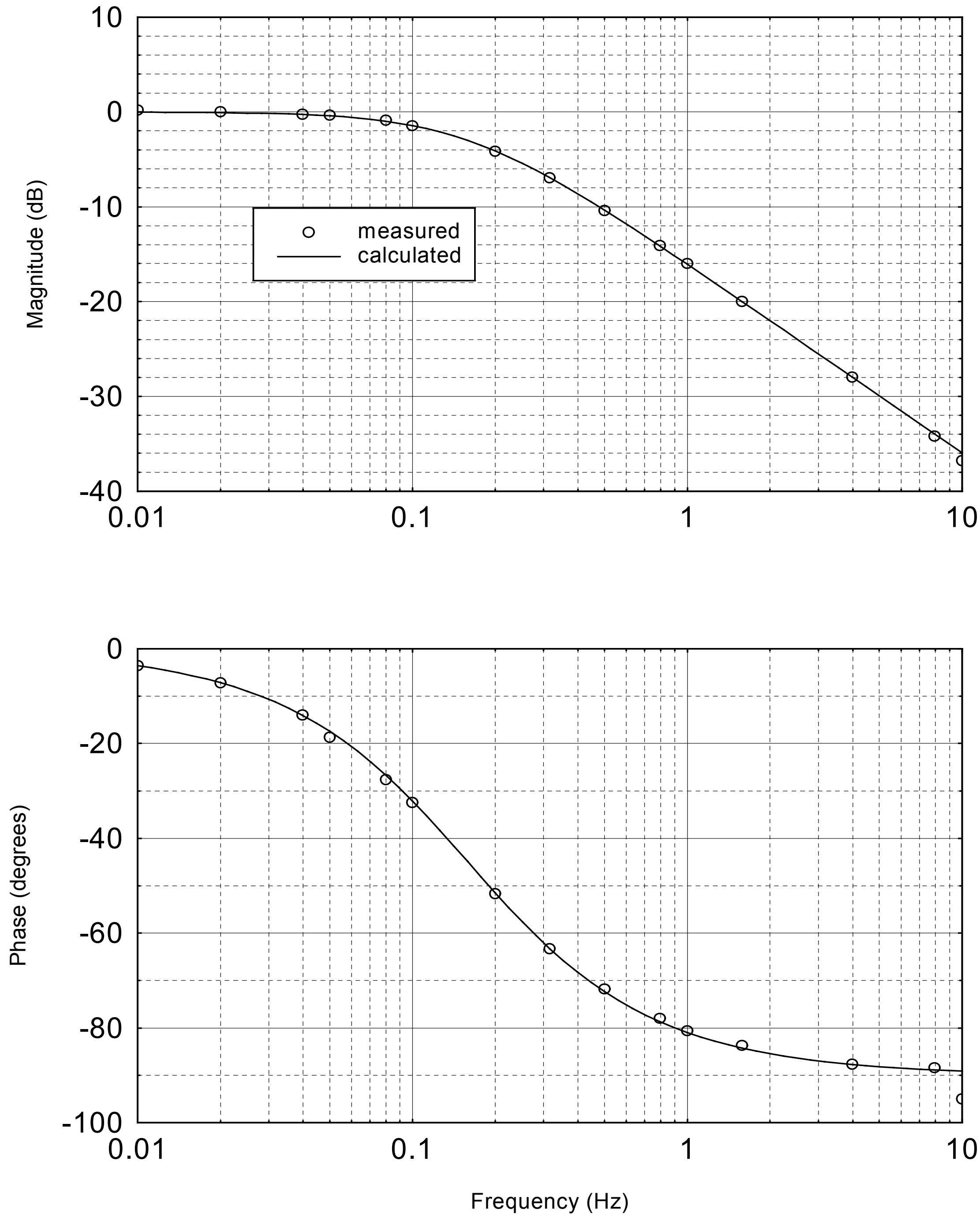


Figure B3. IPSS Lab Measurements Lowpass Filter Transfer Function

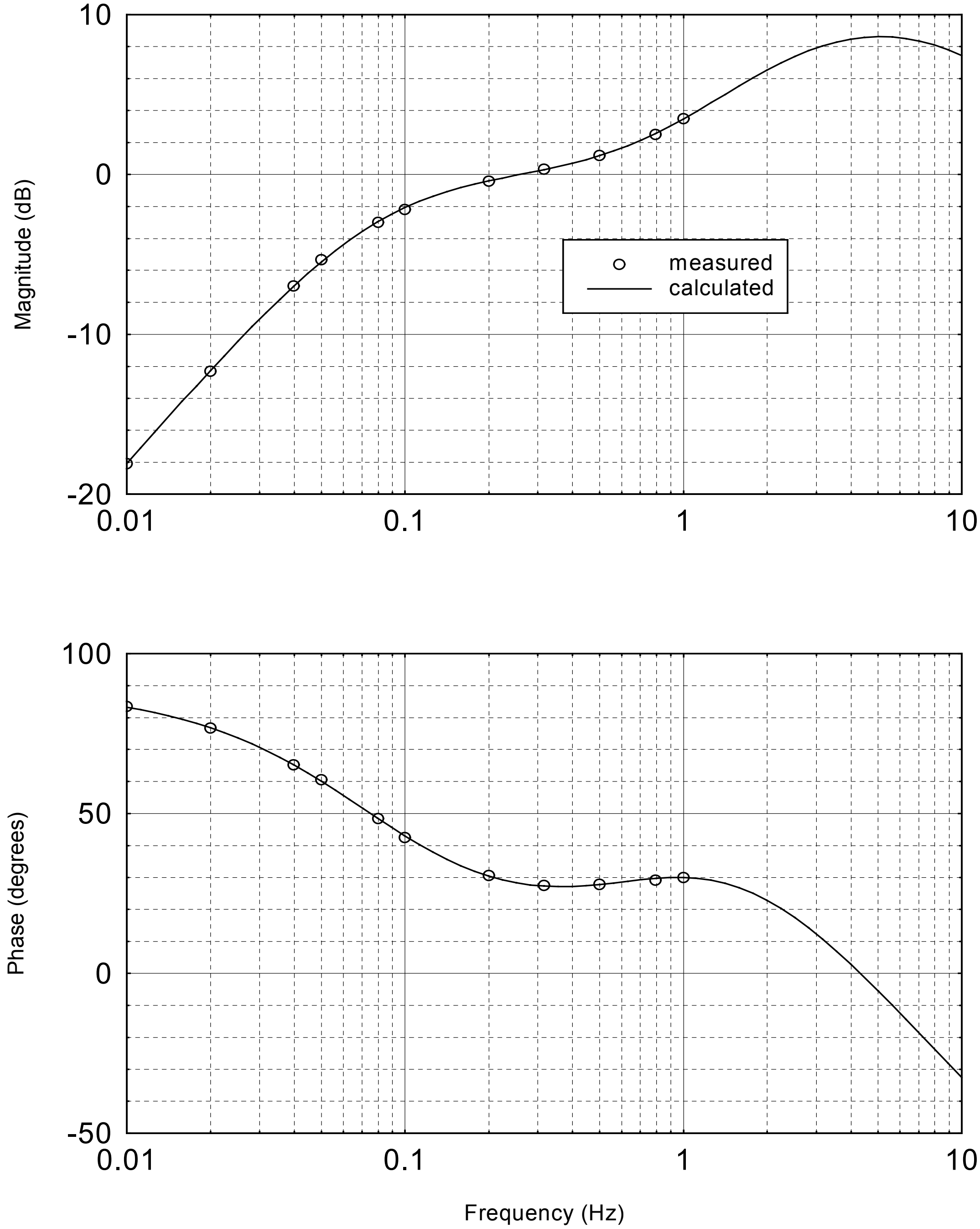


Figure B4. IPSS Lab Measurements Highpass and Phase Lead Transfer Function

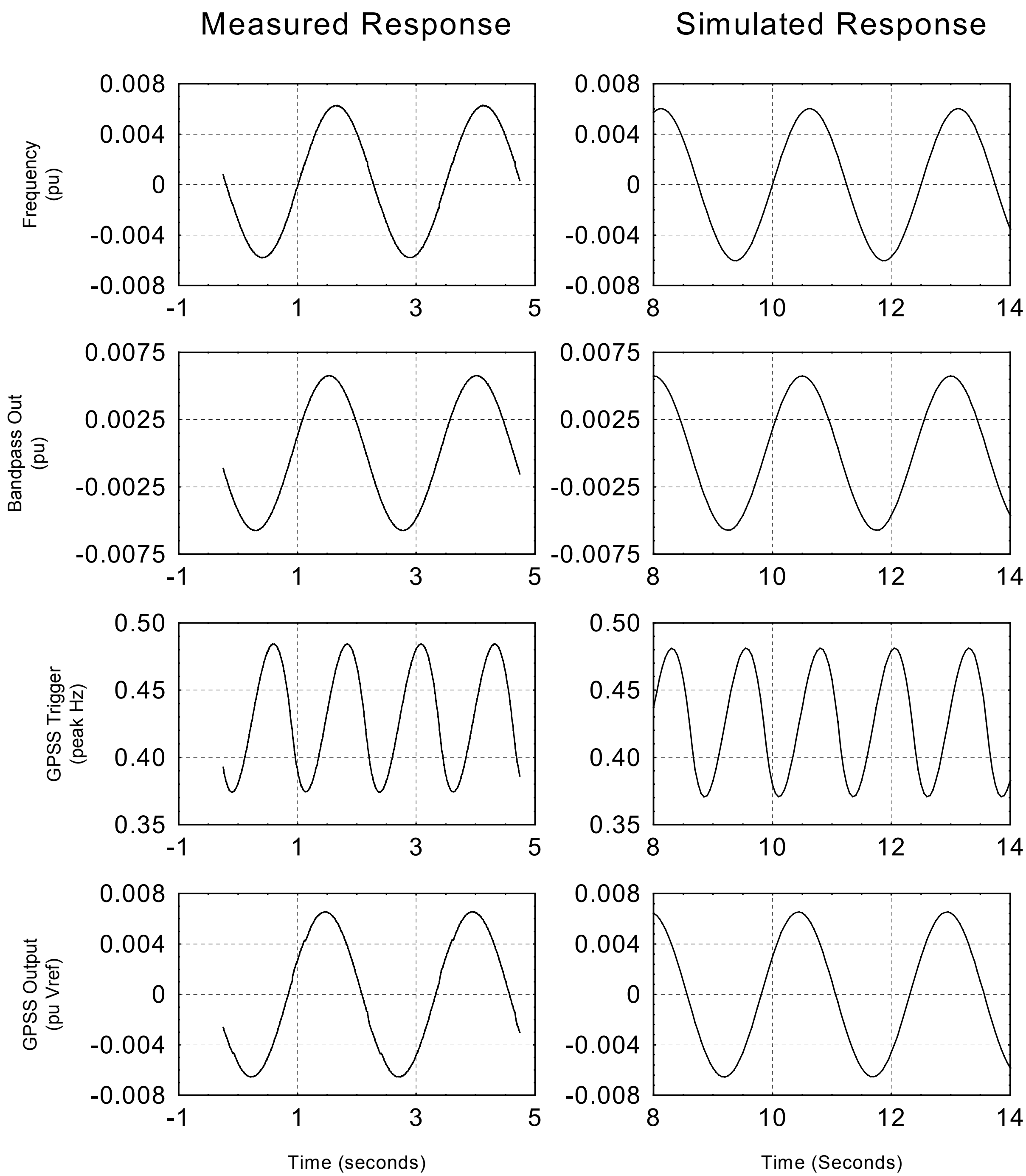


Figure B5. IPSS Lab Measurements – Operation of GPSS Trigger

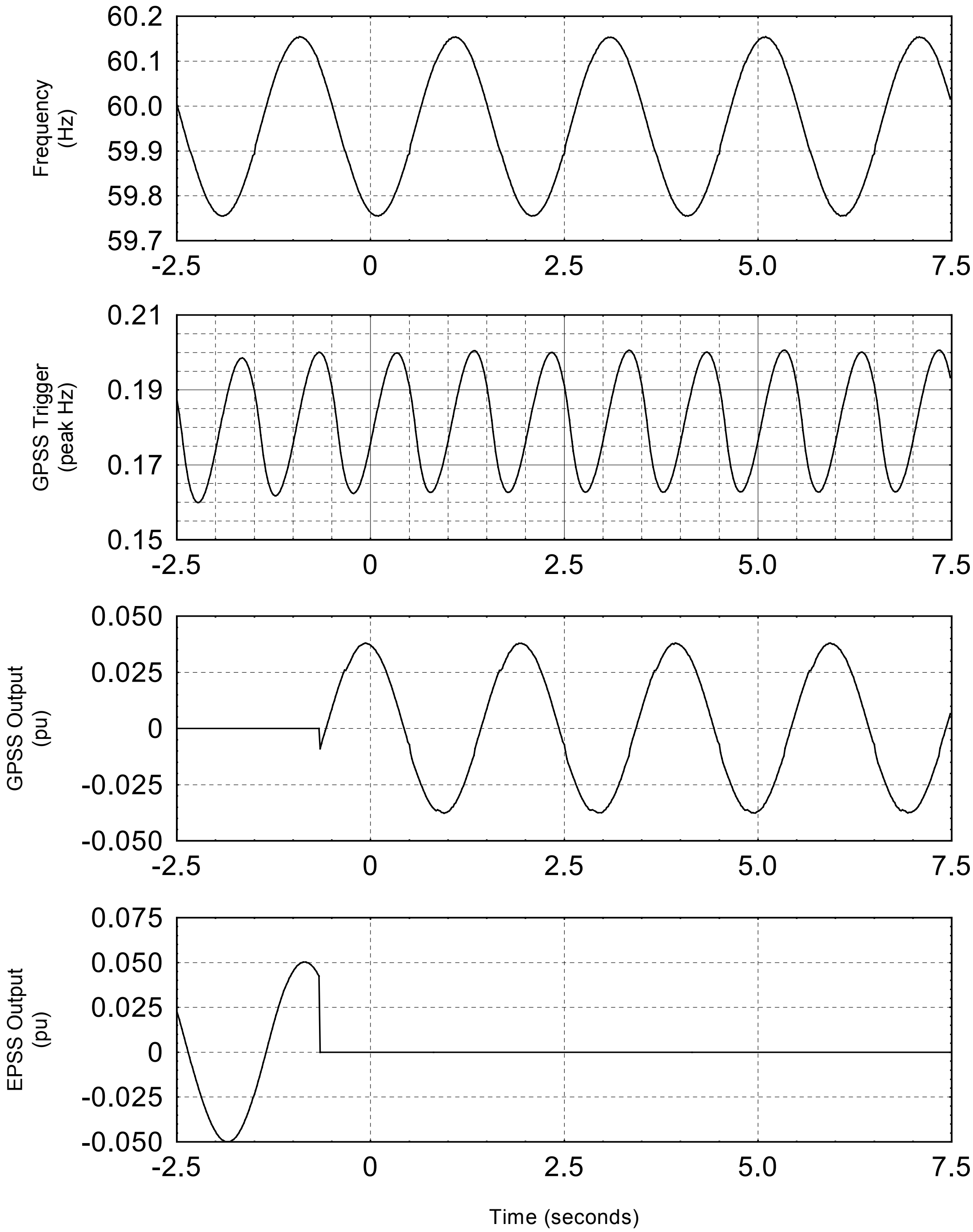


Figure B6. IPSS Laboratory Tests Operation of IPSS Exclusive-Mode Switching

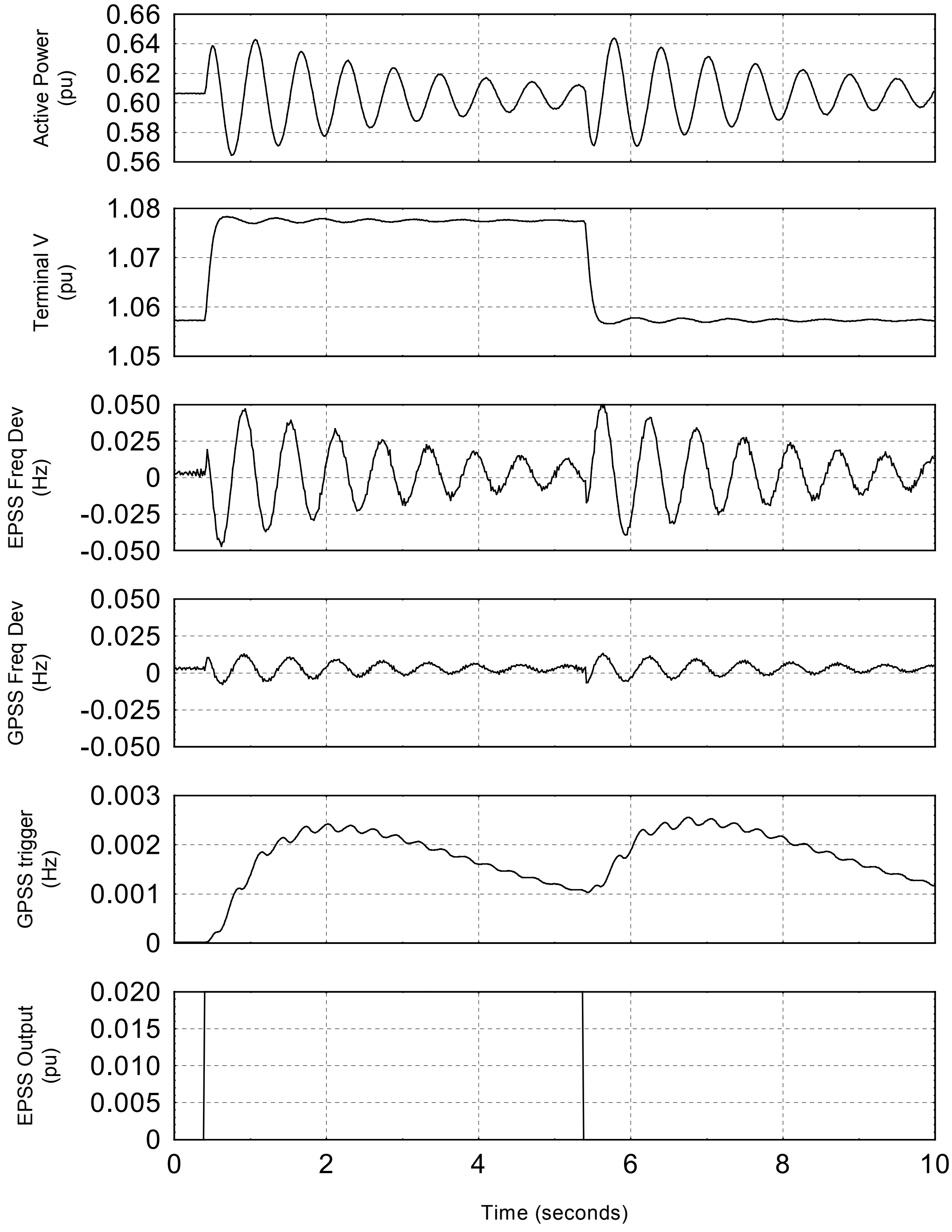


Figure B7. IPSS Laboratory Measurements RTDS Test of EPSS Function, Ks = 0

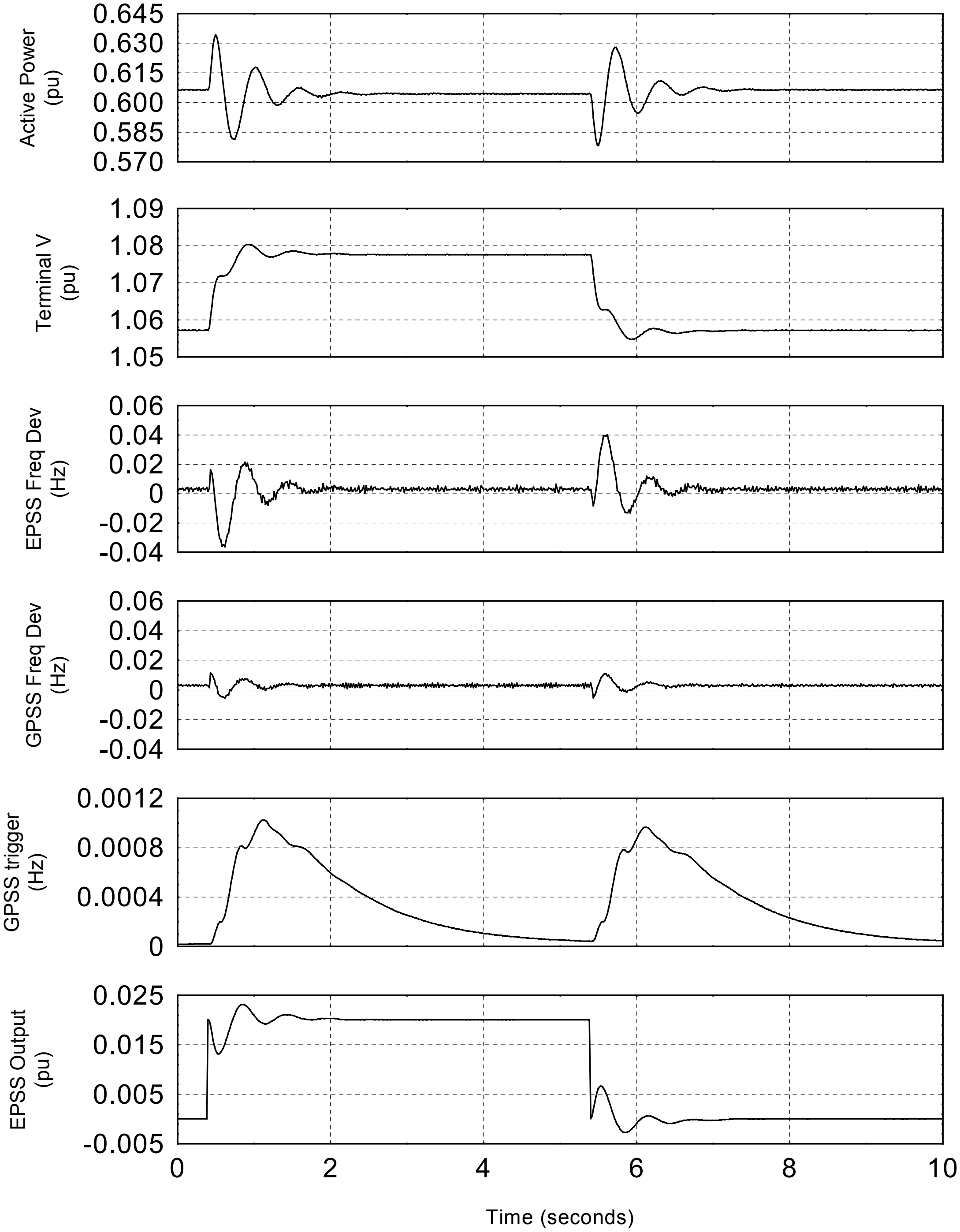


Figure B8. IPSS Laboratory Measurements RTDS Testing of EPSS Function, Ks = 12.5

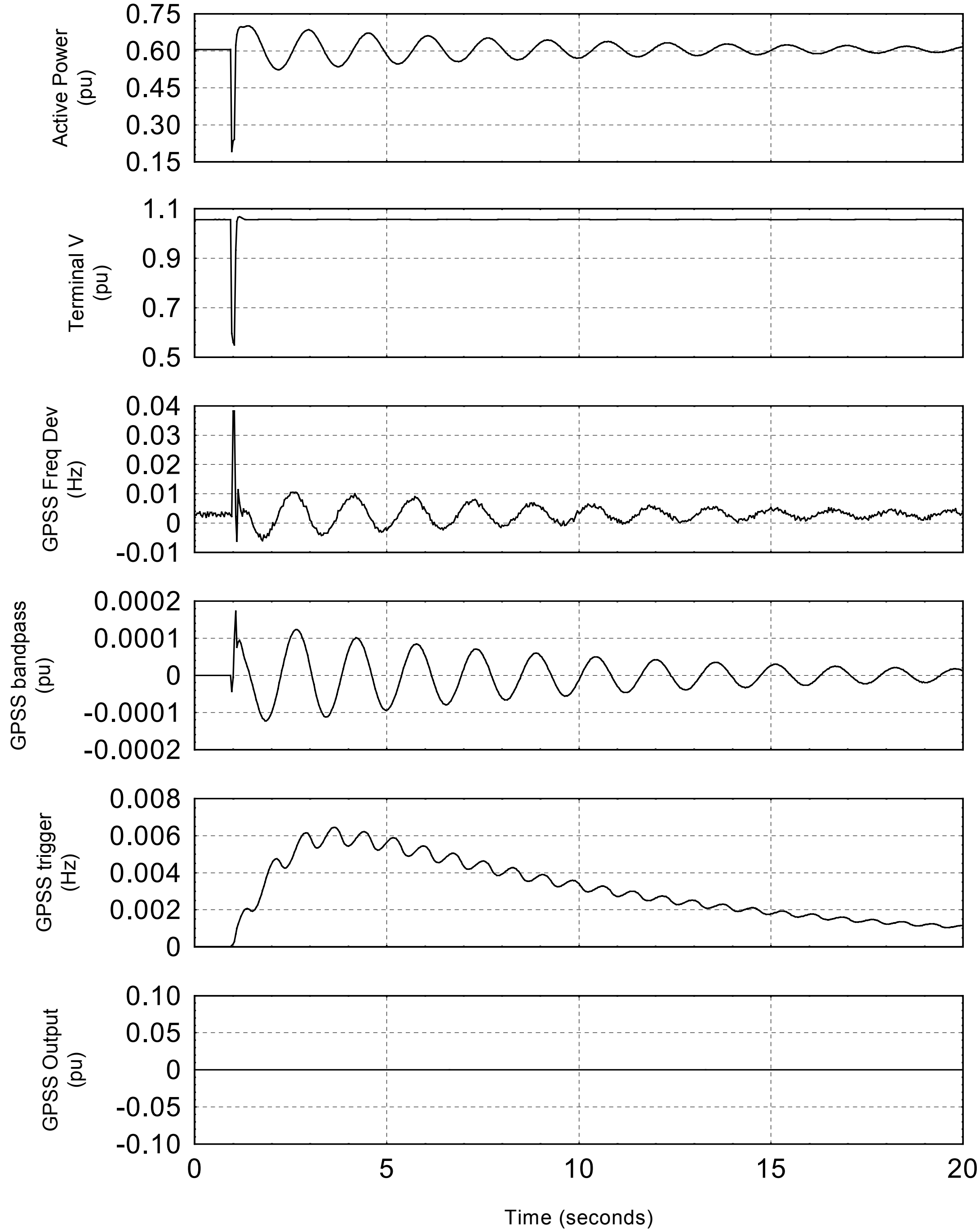


Figure B9. IPSS Laboratory Measurements RTDS Test of GPSS Function, Ks = 0

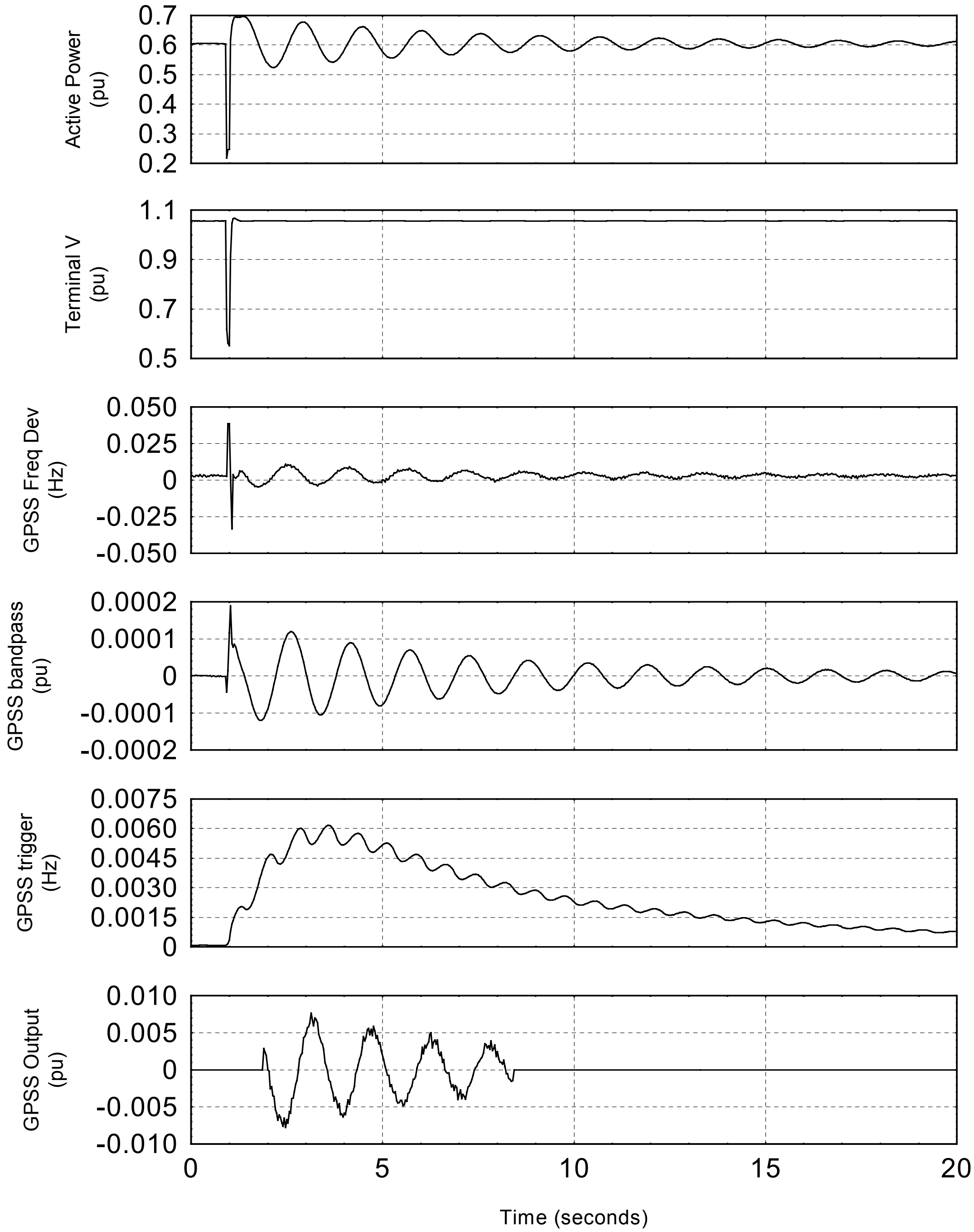


Figure B10. IPSS Laboratory Measurements RTDS Test of GPSS Function, Ks = -50

Appendix II
Site Test Plan
Alamitos Unit 6, December 15-20, 1997

1.0 Inspection of Hardware and Wiring

Unit Conditions – Generators' load levels (not critical). EPSS disconnected from LP unit exciter, IPSS disconnected from HP unit exciter and governor.

	Description	Result
1	Check that hardware modifications have been made to both the IPSS and EPSS (refer to list transmitted to T. Eberly 11/12/97). Inspect each unit for possible damage caused during transit.	Done 12/16/97 Replaced damaged processor board. CPU had been pulled out and pins bent (ser# 302382025). New CPU ser# 301317024
2	Check connection of PT and CT input modules (PSS3 and PSS1) via isolating switches.	Done 12/16/97
3	Check connection of field voltage transducer output to PSS5 module input.	Done 02/10/98
4	Check connection of "EPSS on/off" contact (output #1, PSS13) to station control logic.	Done 12/16/97
5	Check connection of "DPSS trouble" contact (output #2, PSS13) to station control logic.	Done 02/10/98
6	On IPSS unit, check connection of "GPSS on/off" contact (output #4, PSS13) to station control logic.	Done 02/10/98
7	Check connection of "EPSS on/off" input (input #2, PSS11) through station logic.	Done 12/16/97
8	On IPSS unit, check connection of "GPSS on/off" input (input #3, PSS11) through station logic.	Done 12/16/97
9	Check connection of EPSS output (PSS9-2 card on EPSS unit and PSS9B card on IPSS) to external relay logic and voltage regulator control winding.	Refer to SCE dwg for final.
10	Check connection of GPSS output to governor valve control logic.	Inserting 499K as R20 PSS9B 12/17/97.

2.0 Software Loading/Verification

Unit Conditions – Generators' load levels (not critical). EPSS disconnected from LP unit exciter, IPSS disconnected from HP unit exciter and governor.

	Description	Result
1	Connect RS232 to EPSS unit. Apply ac power to unit and connect portable computer for communication. Confirm that unit is functioning. Halt DPSS unit through software.	Done 12/16/97
2	Turn off ac supply, remove processor card and disconnect battery. Short terminals to clear battery-backed memory. Replace battery. Re-install processor card and apply ac power.	Not necessary, upload performed without this step.
3	Upload new program and configuration file to FLASH EEPROM.	Done 12/16/97 Problem in running XFLASH with SCE Toshiba laptop – will attempt with another machine when testing complete.
4	Load Host software and check for correct operation and version numbers (under Help menu).	Done Host V2R9, DPSS V4R3 Modified to DPSS V4R4 to correct test signal problem.
5	Enter each menu and modify settings as required to the starting values	Done 12/16/97, settings recorded in workbook
6	Repeat steps 1 through 5 for IPSS on HP unit.	Done 12/16/97 re-loaded 02/12/98 with V4R4

3.0 Preparation/Off-line Measurements

Unit Conditions – Exciters energized. Generators' load levels not critical.

	Description	Result
1	Measure power supply outputs on EPSS.	Done 12/16/97
2	Check for alarms or any other indications of problems.	Done 12/16/97
3	Check operation of remote status inputs from control room.	Done 02/09/98
4	Test contact outputs using host program, and check local alarms in control room.	Done 02/09/98 SCE to re-arrange control room annunciation.
5	Repeat steps 1 through 4 for IPSS.	Done 12/16/97

4.0 Exciter Tuning LP Unit

Unit Conditions – LP exciter energized on AVR control, generator at rated terminal voltage. HP exciter on MANUAL control for part of the tests.

	Description	Result
1	Verify PT input signals and test points on EPSS printed circuit board.	Done 09/02/98
2	Check calculated voltage and frequency quantities.	Done 09/02/98
3	Apply CT input signals to the EPSS and compare readings with available meters.	CT polarities reversed 09/02/98
4	Turn EPSS gain to zero, and place EPSS in-service by enabling all hardware and software switches. Monitor exciter quantities and terminal voltage to ensure that there is no disturbance to the normal operation of the AVR.	Done 02/09/98
5	Switch the HP exciter to MANUAL control. Using DPSS test supply, inject small voltage change and measure resulting terminal voltage change. Calibrate EPSS software output scaling.	Done 02/09/98
6	Using software test facility, apply 1% terminal voltage reference step into exciter AVR control winding. Measure resulting exciter and generator output changes on the stabilizer data recorder and external direct-writing recorder.	Done 02/09/98
7	Measure signal on field voltage transducer output (modify calibration if necessary).	Done 02/09/98
8	Examine overall closed-loop voltage regulator response. Switch LP unit exciter to MANUAL. Adjust the AVR gain (decrease R1), the damping panel gain (decrease R7) and the damping time constant (decrease R8) to achieve the recommended values.	Done 02/10/98
9	Disconnect the damping panel input and measure the transfer function. Compare with calculated values for the recommended settings and adjust as required. Once complete, restore normal connections.	Done 02/10/98
10	Transfer LP unit back to AVR control, and perform step response measurement (step 6). Compare measured response with simulations of recommended settings. If response appears to match desired level, continue on to next step. If not, repeat steps 8, 9, and 10 until desired response is achieved.	Done 02/10/98
11	Perform measurement of closed-loop voltage regulator transfer function. Compare response with simulation of recommended settings, and the EPSS tuning data. If a good match exists, continue to next step. If the response does not match, repeat steps 9 and 10 until an adequate match is obtained.	Done 02/10/98

5.0 Exciter Tuning HP Unit

Unit Conditions – HP exciter energized on AVR control, generator at rated terminal voltage. LP exciter on MANUAL control for part of the tests.

	Description	Result
1	Verify PT input signals and test points on IPSS printed circuit board.	Done 02/10/98
2	Check calculated voltage and frequency quantities.	Done 02/10/98
3	Apply CT input signals to the IPSS and compare readings with available meters.	Done 02/10/98
4	Turn EPSS/GPSS gain to zero. Disconnect GPSS output signal to governor valve control. Place EPSS in-service by enabling all hardware and software switches. Monitor exciter quantities and terminal voltage to ensure that there is no disturbance to the normal operation of the AVR.	Done 02/10/98
5	Switch the LP exciter to MANUAL control. Using the software test supply, inject small voltage change and measure resulting terminal voltage change. Calibrate EPSS software output scaling.	Done 02/10/98
6	Using software test facility, apply 1% terminal voltage reference step into exciter AVR control winding. Measure resulting exciter and generator output changes on the stabilizer data recorder and external direct-writing recorder.	Done 02/10/98
7	Measure signal on field voltage transducer output (modify calibration if necessary).	Done 02/10/98
8	Examine overall closed-loop voltage regulator response. Switch HP unit exciter to MANUAL. Adjust the AVR gain (decrease R1), the damping panel gain (decrease R7) and the damping time constant (decrease R8) to achieve the recommended values.	Done 02/10/98
9	Disconnect the damping panel input and measure the transfer function. Compare with calculated values for the recommended settings and adjust as required. Once complete, restore normal connections.	Not done based on results obtained on LP unit
10	Transfer HP unit back to AVR control, and perform step response measurement (step 6). Compare measured response with simulations of recommended settings. If response appears to match desired level, continue on to next step. If not, repeat steps 8, 9, and 10 until desired response is achieved.	Done 02/10/98
11	Perform measurement of closed-loop voltage regulator transfer function. Compare response with simulation of recommended settings, and the EPSS tuning data. If a good match exists, continue to next step. If the response does not match, repeat steps 9 and 10 until an adequate match is obtained.	Obtained a much lower bandwidth and correspondingly higher hase lag at all frequencies. No further tuning performed.
12	Restore both units to AVR control. Repeat step response measurement and record overall response. Examine the reactive power changes and adjust reactive compensation if necessary.	Done 02/11/98

6.0 LP Excitation Stabilizer Measurements

Unit Conditions – HP and LP units running at high load (>70 percent nameplate MVA), exciters on AVR control.

	Description	Result
1	On LP unit, perform on-line step disturbance test with EPSS gain set to zero. Download captured data record and examine the calculated quantities.	Done 02/10/98
2	Increase EPSS gain to 1/10 of recommended setting and repeat the measurement. Gradually increase EPSS gain while monitoring output continuously on direct-writing recorder. Perform measurement at recommended gain.	Done 02/10/98
3	Perform long-term recording, to determine effect on terminal voltage and other output quantities.	Done 02/10/98
4	Increase gain until signs of an exciter mode, or double the recommended gain is achieved.	Done 02/10/98
5	Reduce the gain to the rated level and reduce the unit's excitation as much as is allowable by system and plant constraints. Repeat step response measurement.	Done 02/10/98

7.0 HP Excitation Stabilizer Measurements

Unit Conditions – HP and LP units running at high load (>70 percent nameplate MVA), exciters on AVR control.

	Description	Result
1	On HP unit, perform on-line step disturbance test with EPSS gain set to zero. Download captured data record and examine the calculated quantities.	Converted EPSS to frequency-based design due to extreme levels of phase lead required. Used original settings from the Westinghouse PSS.
2	Increase EPSS gain to 1/10 of recommended setting and repeat the measurement. Gradually increase EPSS gain while monitoring output continuously on direct-writing recorder. Perform measurement at recommended gain.	Done 02/11/98
3	Perform long-term recording, to determine effect on terminal voltage and other output quantities.	Done 02/11/98
4	Increase gain until signs of an exciter mode, or double the recommended gain is achieved.	Done 02/11/98
5	Reduce the gain to the rated level and reduce the unit's excitation as much as is allowable by system and plant constraints. Repeat step response measurement.	Done 02/11/98

8.0 HP Governor Stabilizer Measurements

Unit Conditions – HP and LP units running at high load (>70 percent nameplate MVA), exciters on AVR control.

	Description	Result
1	Turn GPSS gain to zero. Verify that GPSS output is zero. Connect GPSS to governor valve control. Apply small step change in GPSS output and measure the valve position and power output changes on a direct-writing recorder and the stabilizer. Repeat for different modulation sizes. Repeat until 10 MW modulation range is achieved. Calibrate the GPSS output ratio and output limits.	Done 02/11/98
2	Disconnect the GPSS from the governor valve control and perform a transfer function measurement of the valve control input versus active power. Compare with previously submitted results and GPSS phase compensation selection.	Done 02/11/98
3	Set the GPSS settings to the original selections. Monitor the GPSS output and other quantities using the data recorder during ambient operation. Record quantities such as background oscillation levels, GPSS trigger algorithm output, compensated frequency signal output, and GPSS output. Perform both time and frequency-domain measurements of the various quantities. Measure background torsional oscillation components in various signals.	Done 02/11/98
4	Turn the EPSS functions off on both the EPSS and IPSS units. Connect the GPSS output to the governor valve control input. Place the GPSS in-service with a low-trigger threshold level and perform on-line monitoring for an extended period.	Done 02/11/98
5	Inject a 0.3 Hz input signal in the computed frequency input for a few cycles and measure the governor valve and unit responses. Examine data record and adjust settings if necessary. Repeat for longer time duration and capture data record. Repeat analysis.	Done 02/12/98
6	Place the EPSS unit in-service on the HP unit and repeat step 5. Be prepared to turn off the control if coordination problems exist. Based on the results of this test, determine the correct operating mode.	Going to use exclusive mode due to limited effectiveness of EPSS on the HP unit.
7	Place the EPSS in-service on the LP unit and repeat step 5.	Done 02/12/98
8	Adjust settings to proposed in-service levels and perform long-term monitoring of various quantities.	Done 02/12/98
9	Select quantities to be recorded on internal data logger and set auto-triggers to capture data records which could potentially trigger the GPSS function.	Done 02/12/98

Appendix III
Site Commissioning Test Results
Alamitos Unit 6, December 15-20, 1997 and February 9-12, 1998

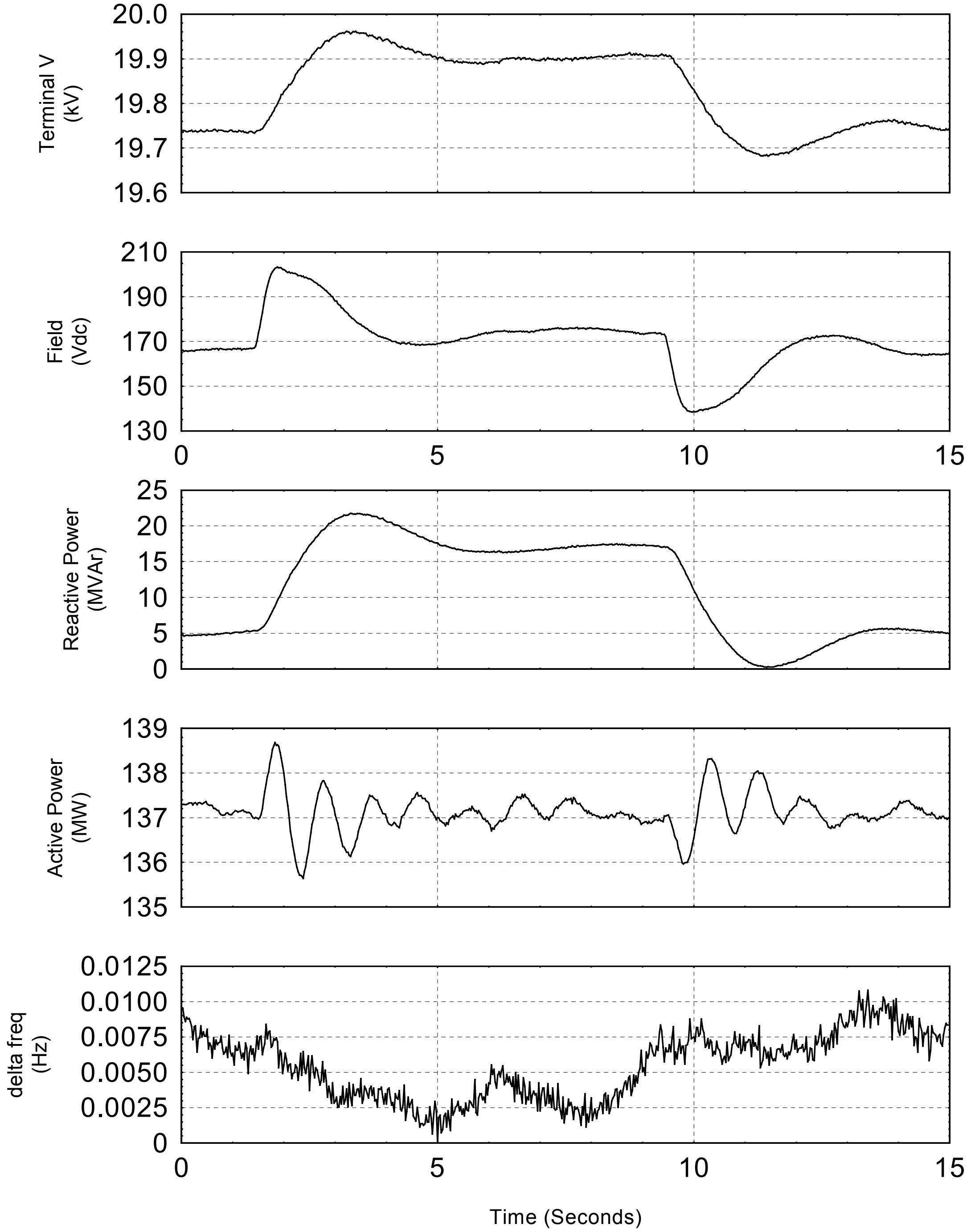


Figure C1. Alamitos Tests – LP Unit Excitation Response As-Found Settings, 02/09/98

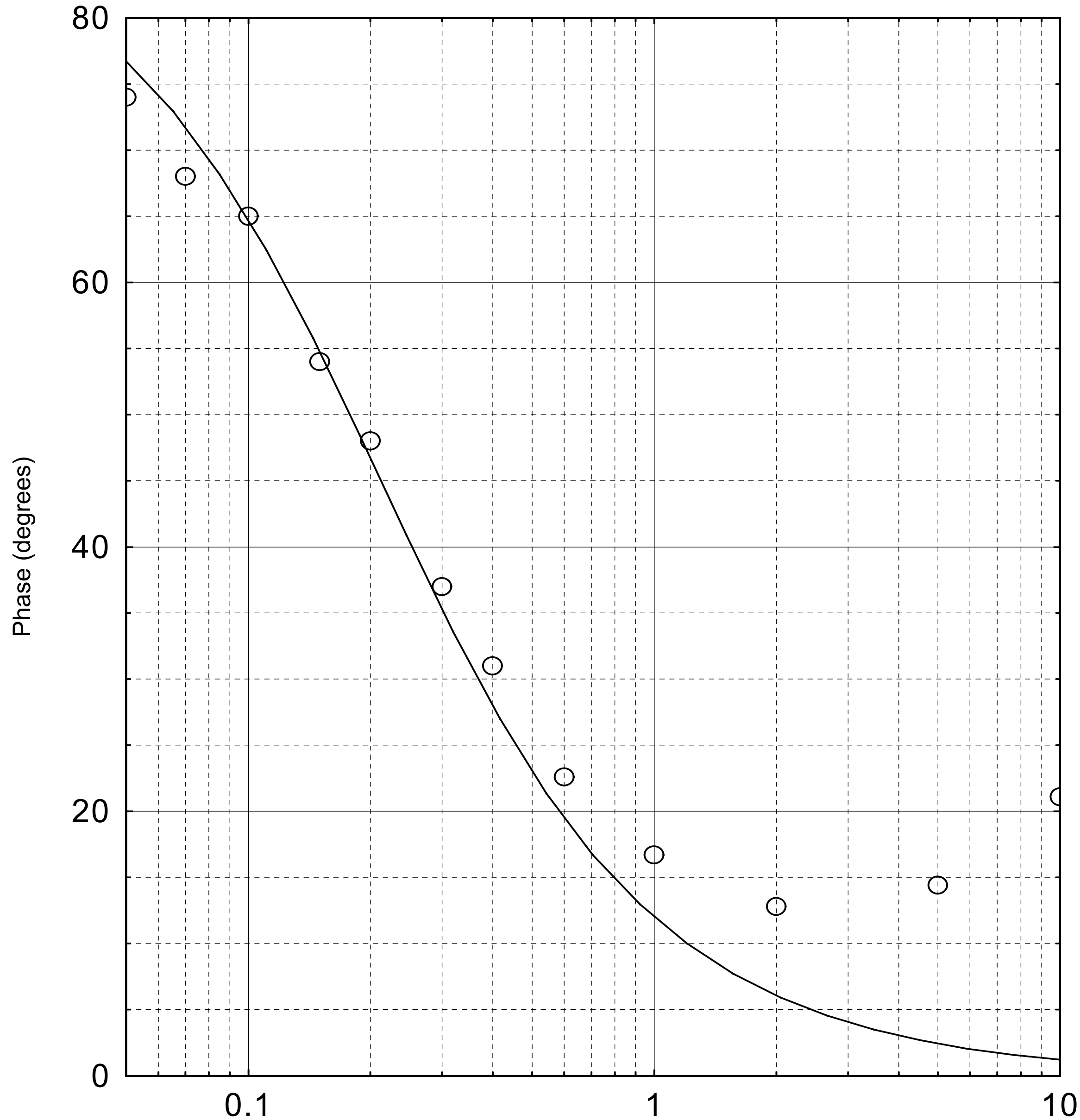


Figure C2. Alamitos Tests – Damping Panel Measure As-Left Settings, 02/09/98

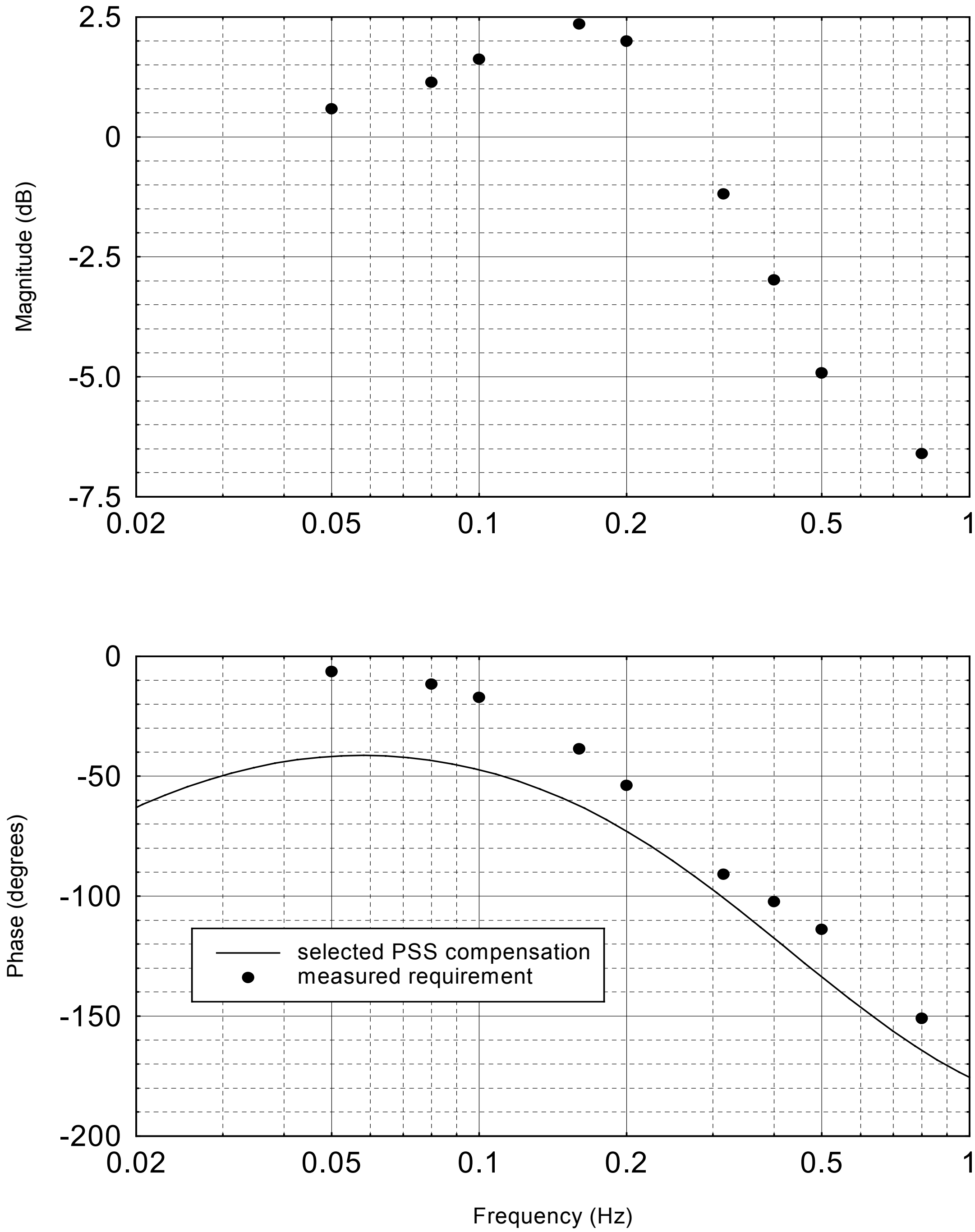


Figure C3. Alamitos Tests – LP Closed-Loop AVR As-Left Measurement and Compensation

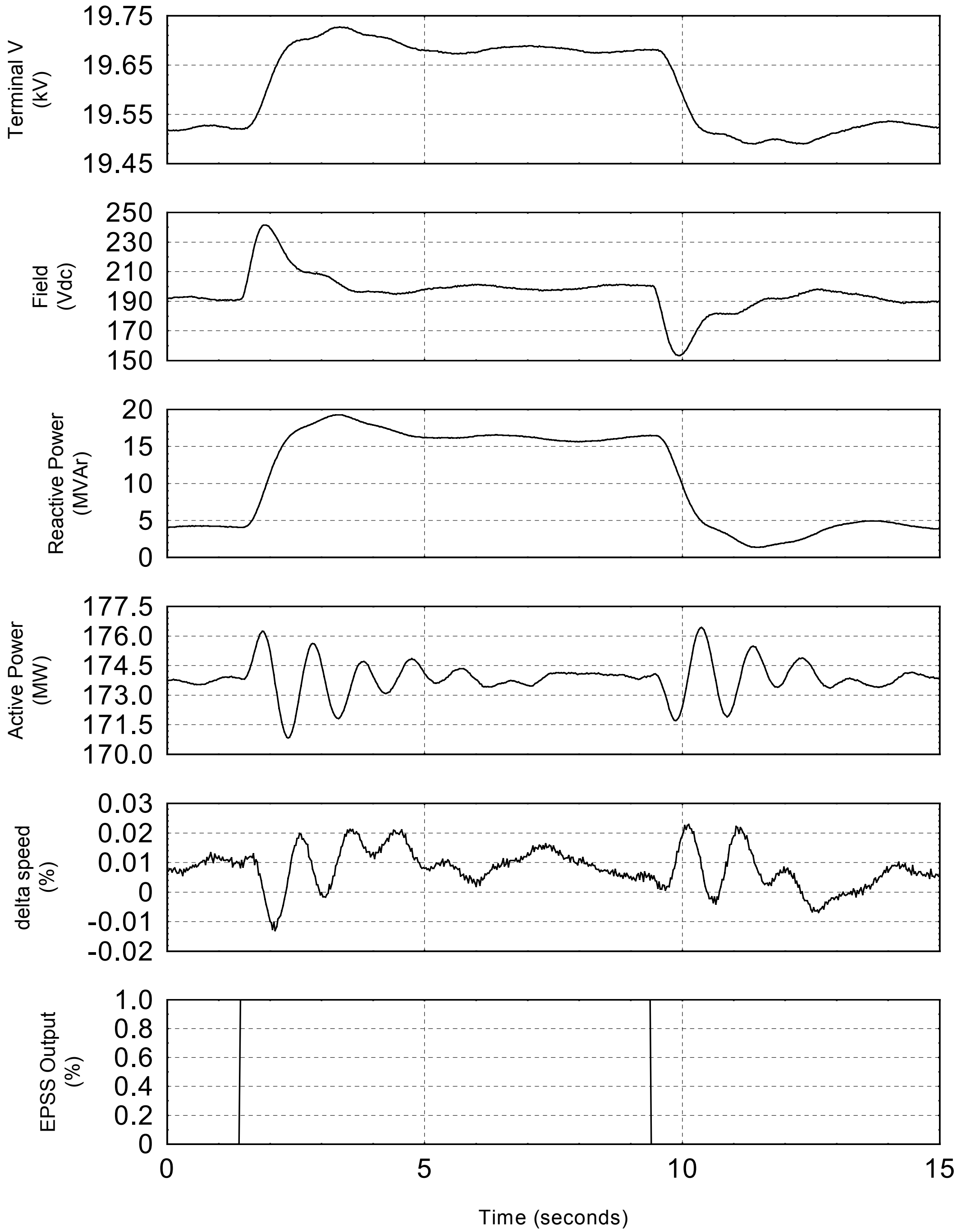


Figure C4. Alamitos Tests – LP Union Excitation Response As-Left Settings to AVR, EPSS Gain = 0, 02/10/98

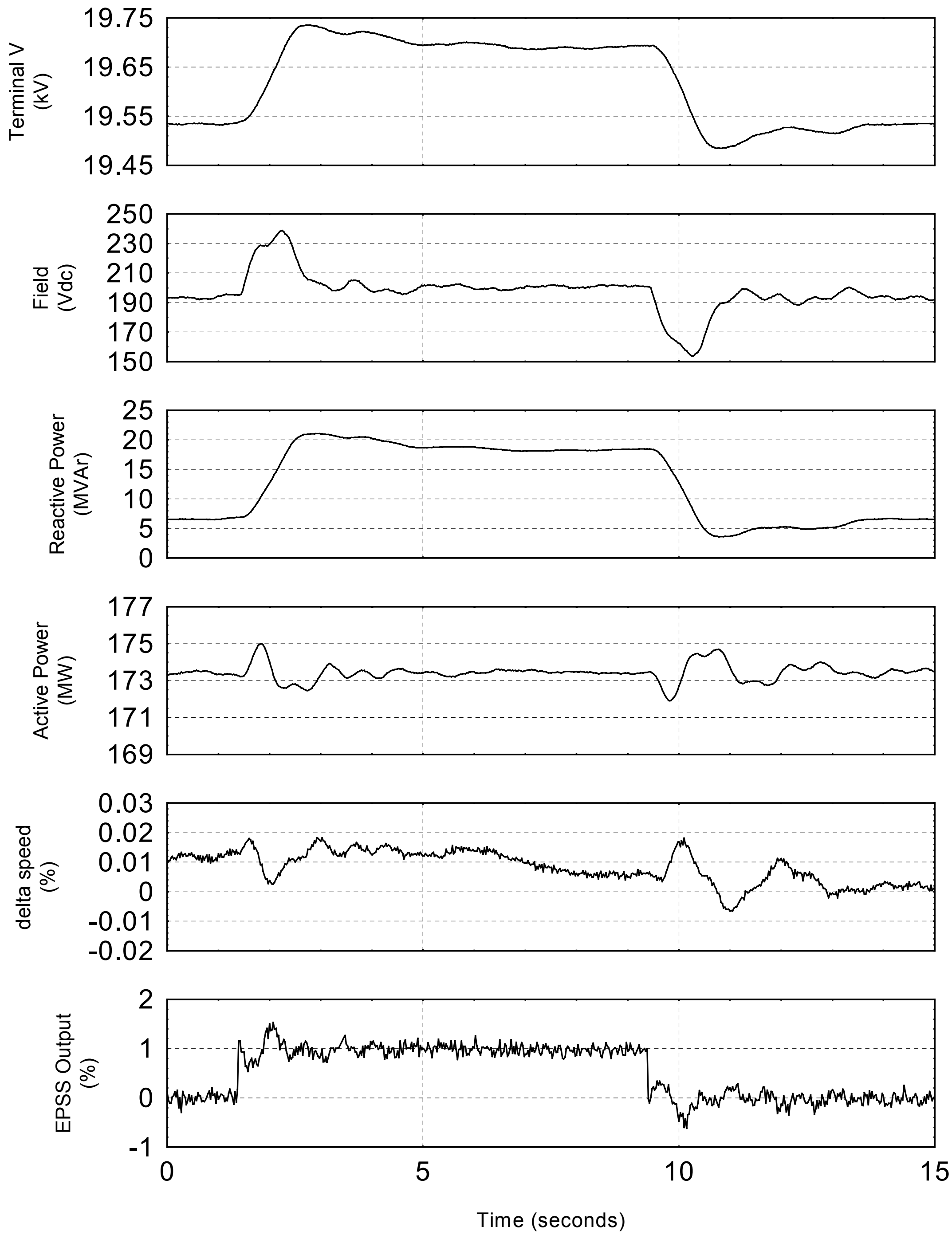


Figure C5. Alamitos Tests – LP Unit Excitation Response EPSS In-Service, Ks = 5.0, 02/10/98

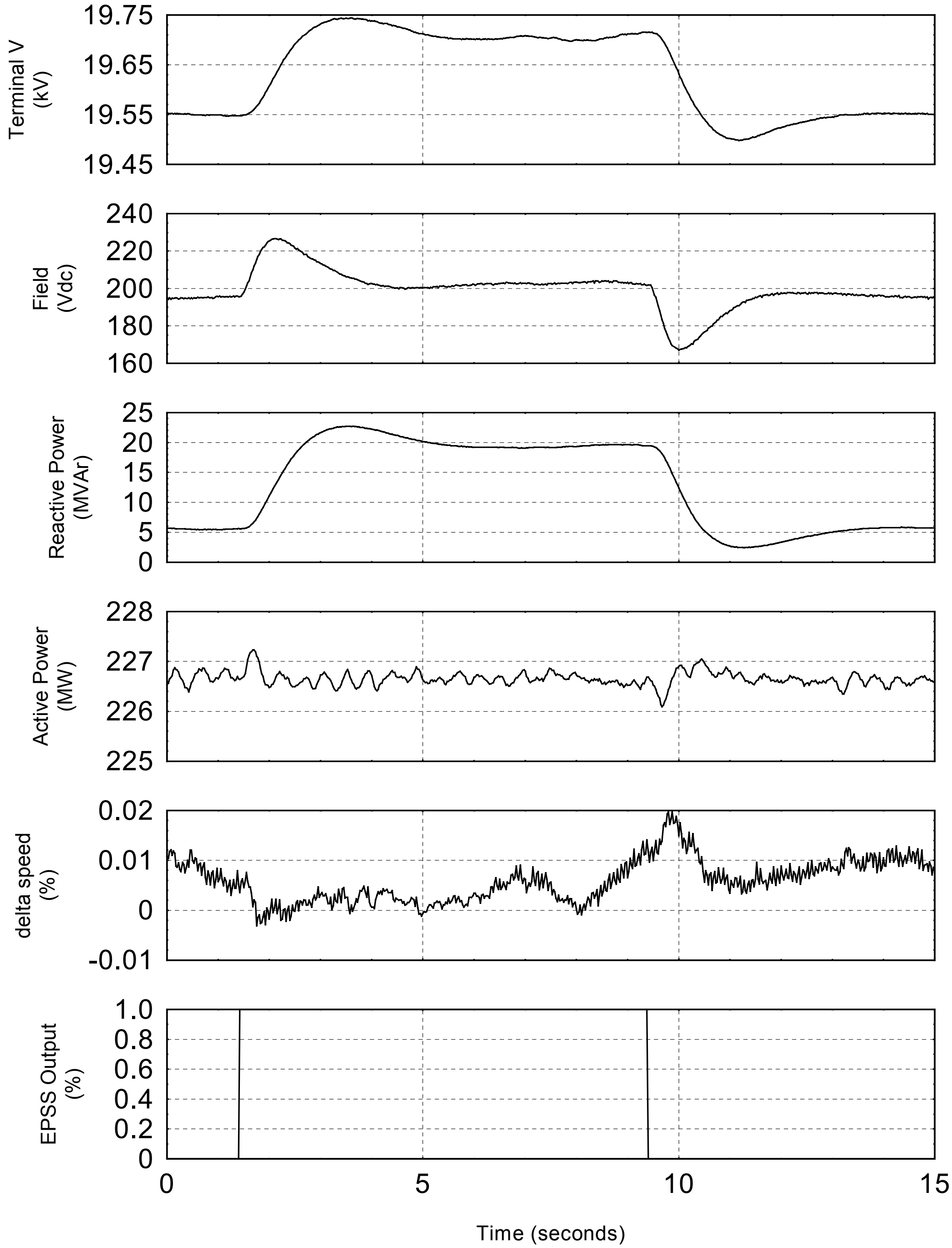


Figure C6. Alamitos Tests – HP Unit Excitation Response As-Left Settings, 02/10/98

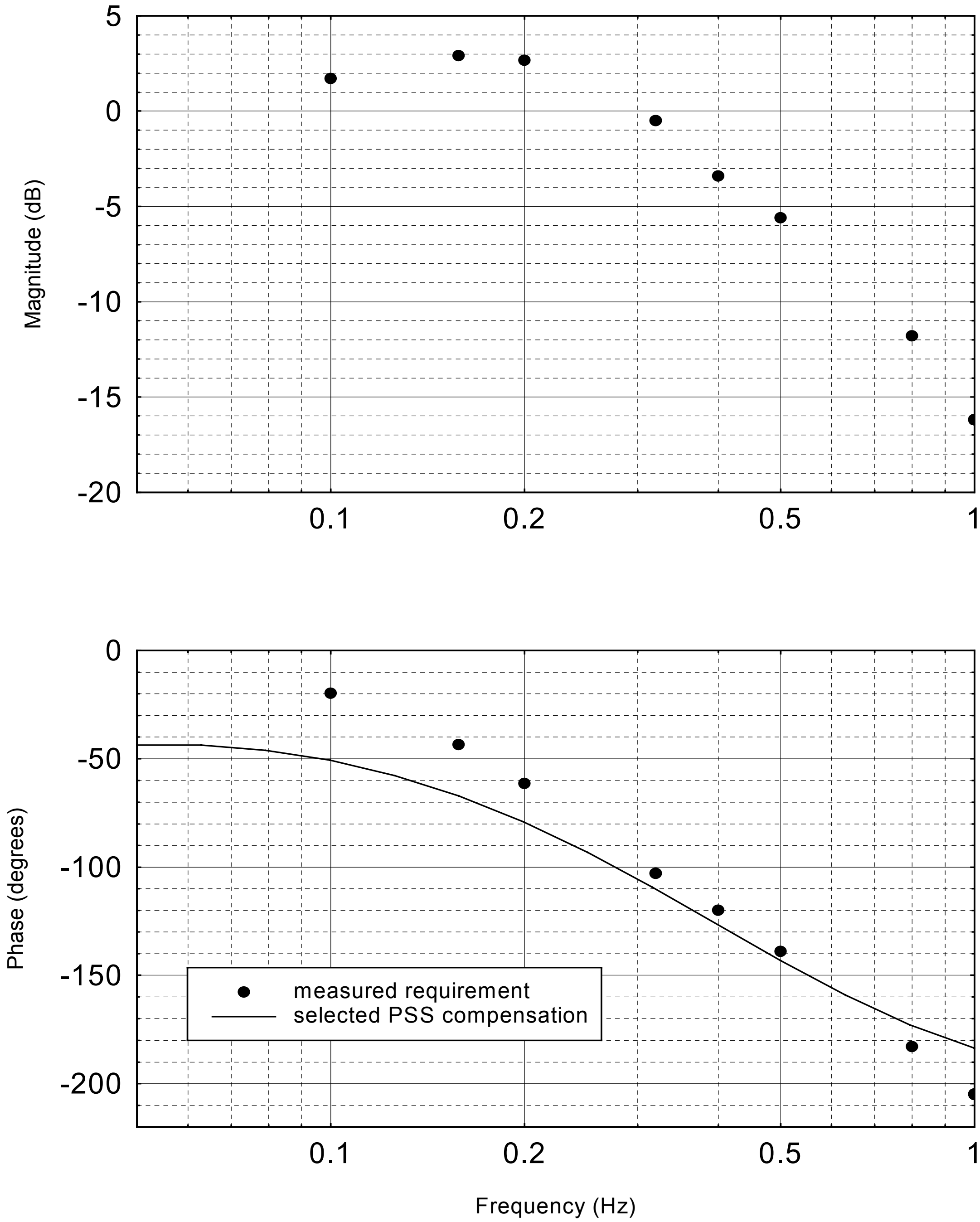


Figure C7. Alamitos Tests – HP Closed-Loop AVR As-Left Measurement and Compensation

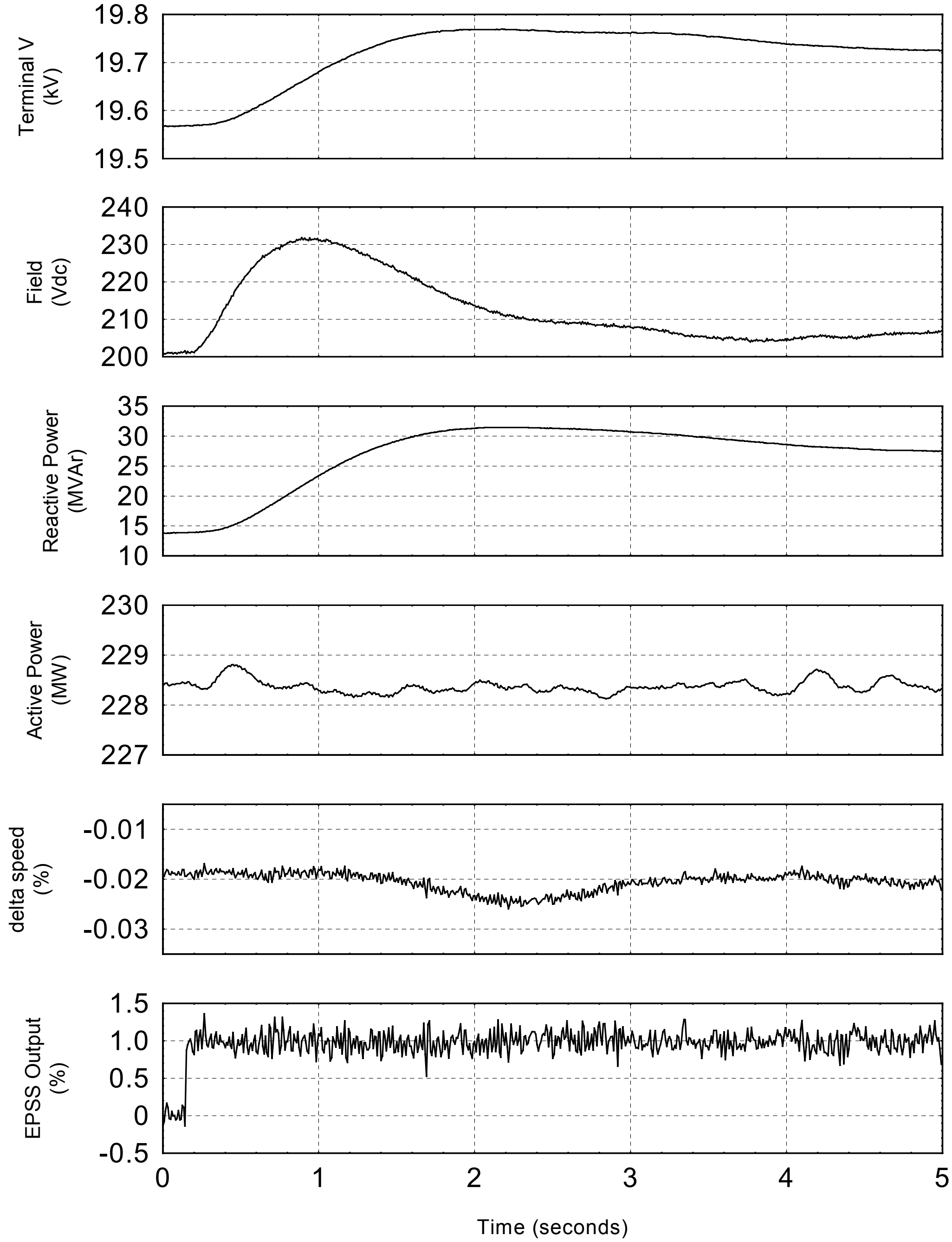


Figure C8. Alamitos Tests – HP Unit Excitation Response Frequency Based EPSS In-Service, Ks = 2.0

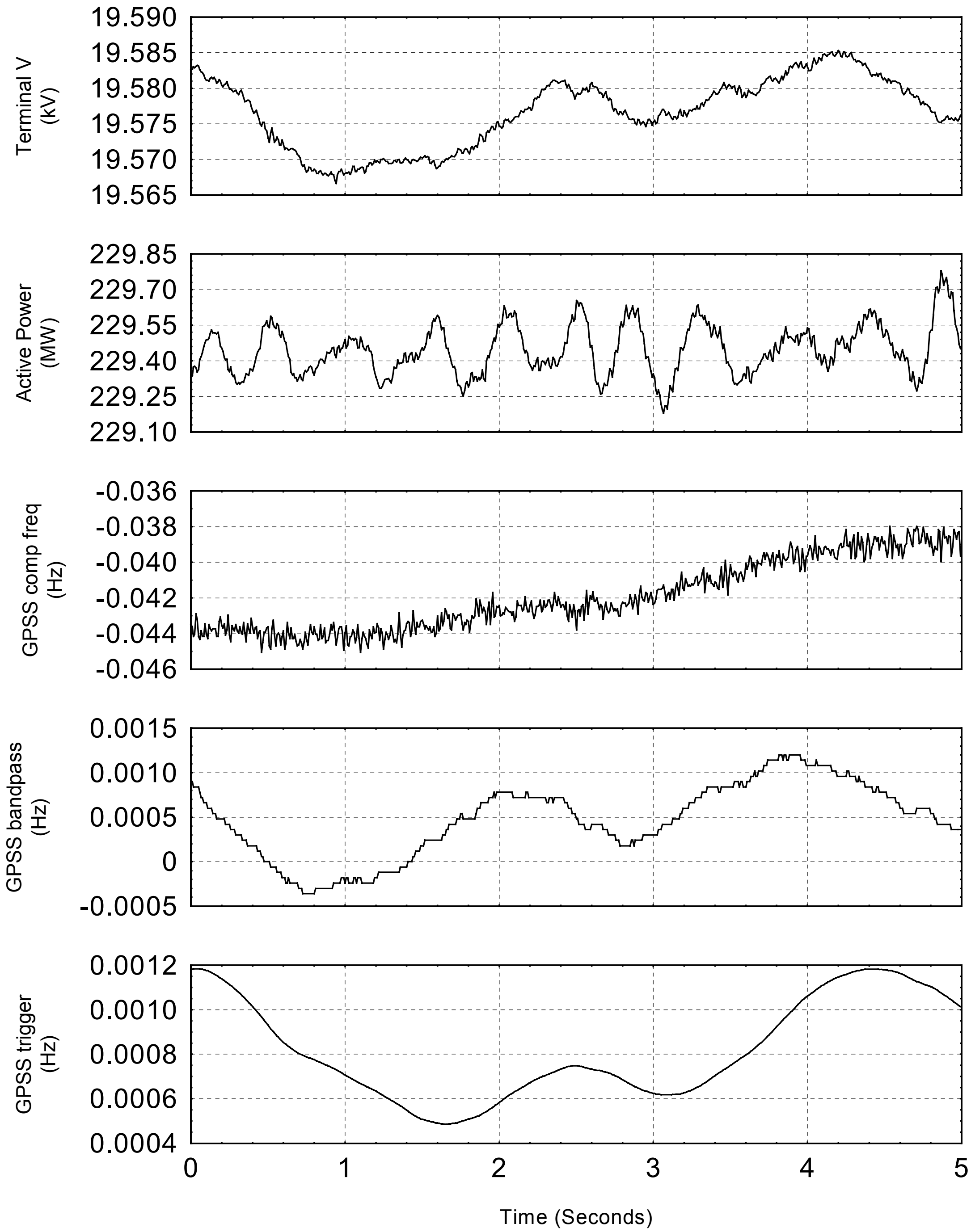


Figure C9. Alamitos Tests – GPSS Trigger Function Ambient Record, 02/11/98

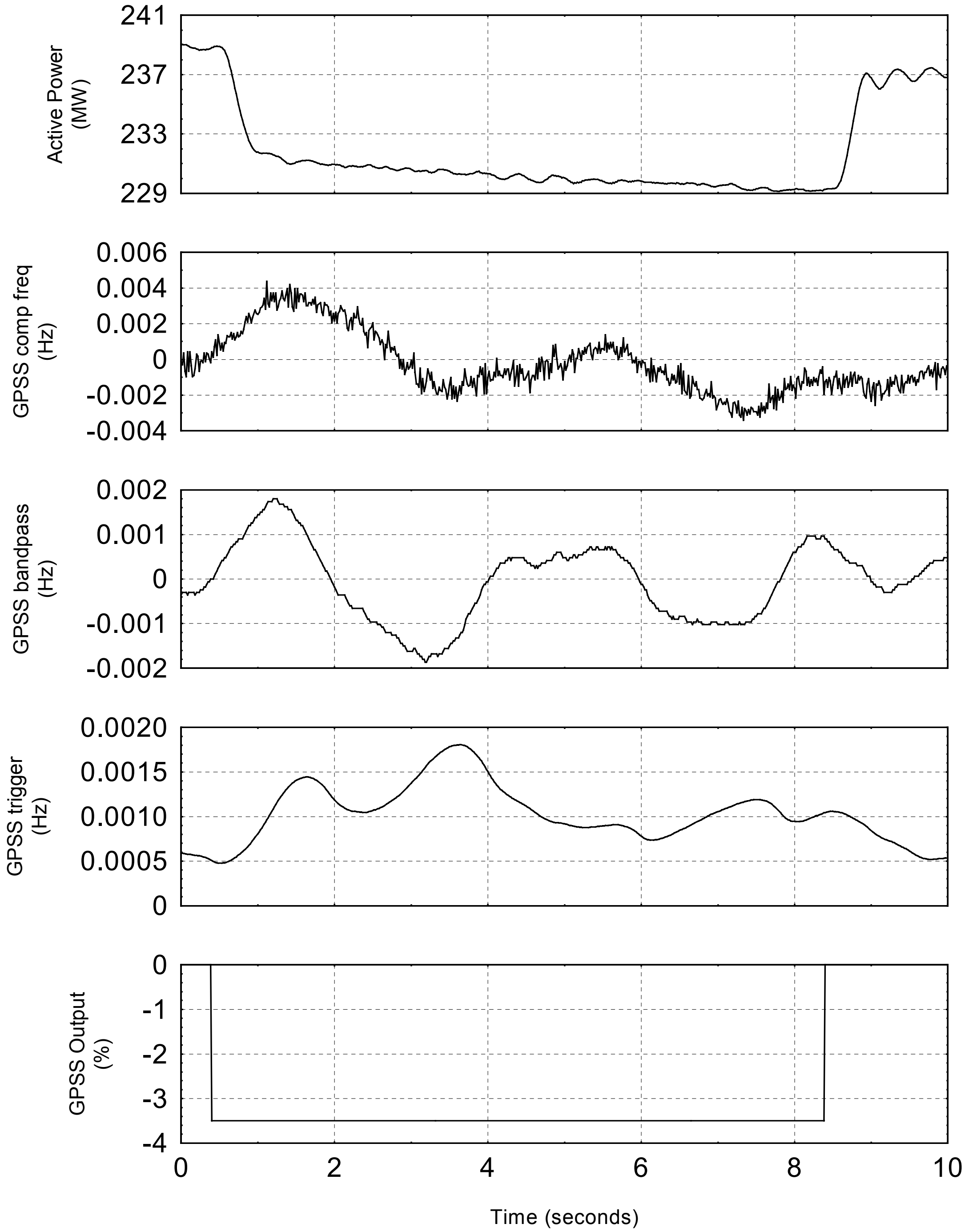


Figure C10. Alamitos Tests – GPSS Function Step Response Measurement, 02/11/98

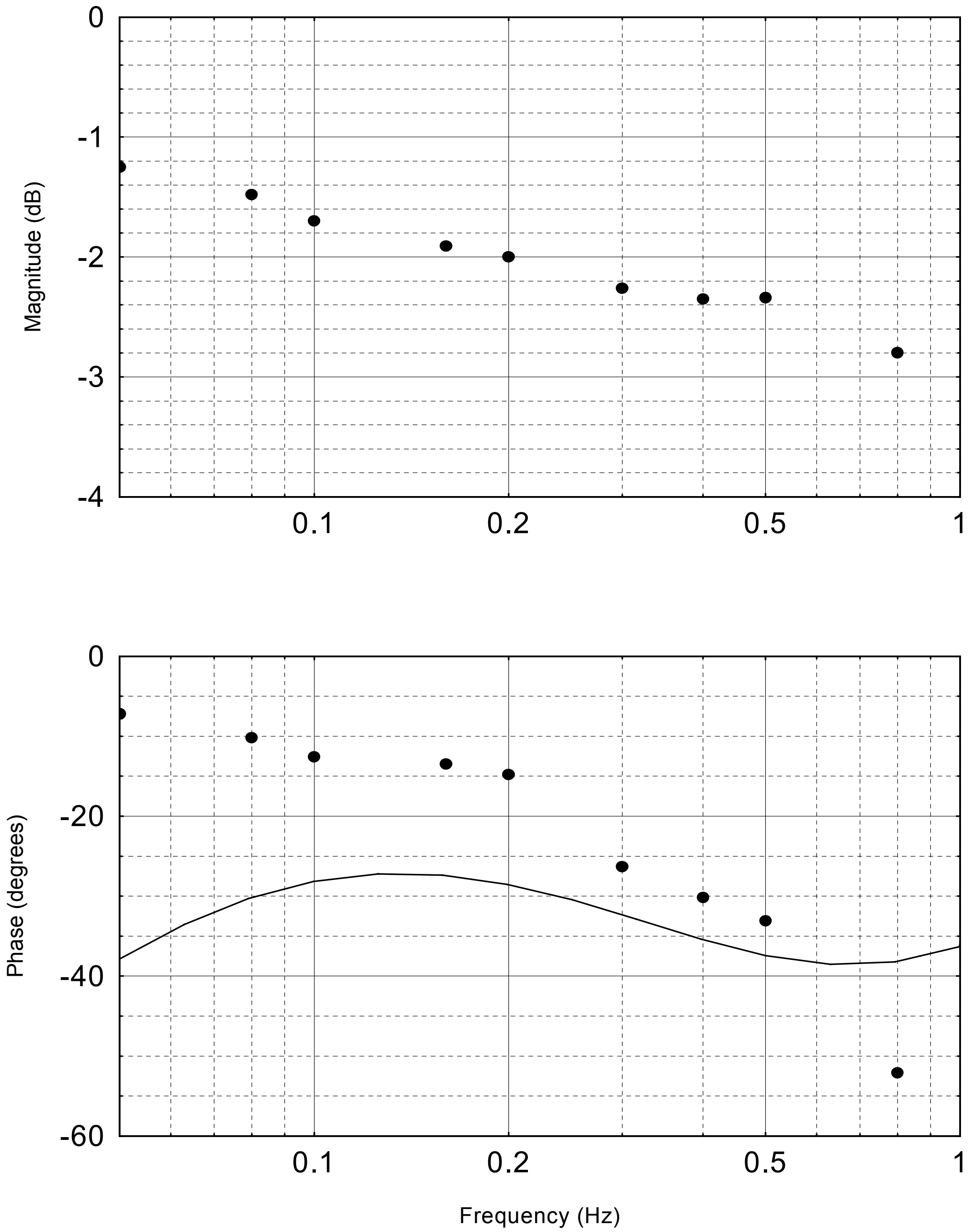


Figure C11. Alamitos Tests – HP Valve Control Power versus Voltage Input, 02/11/98

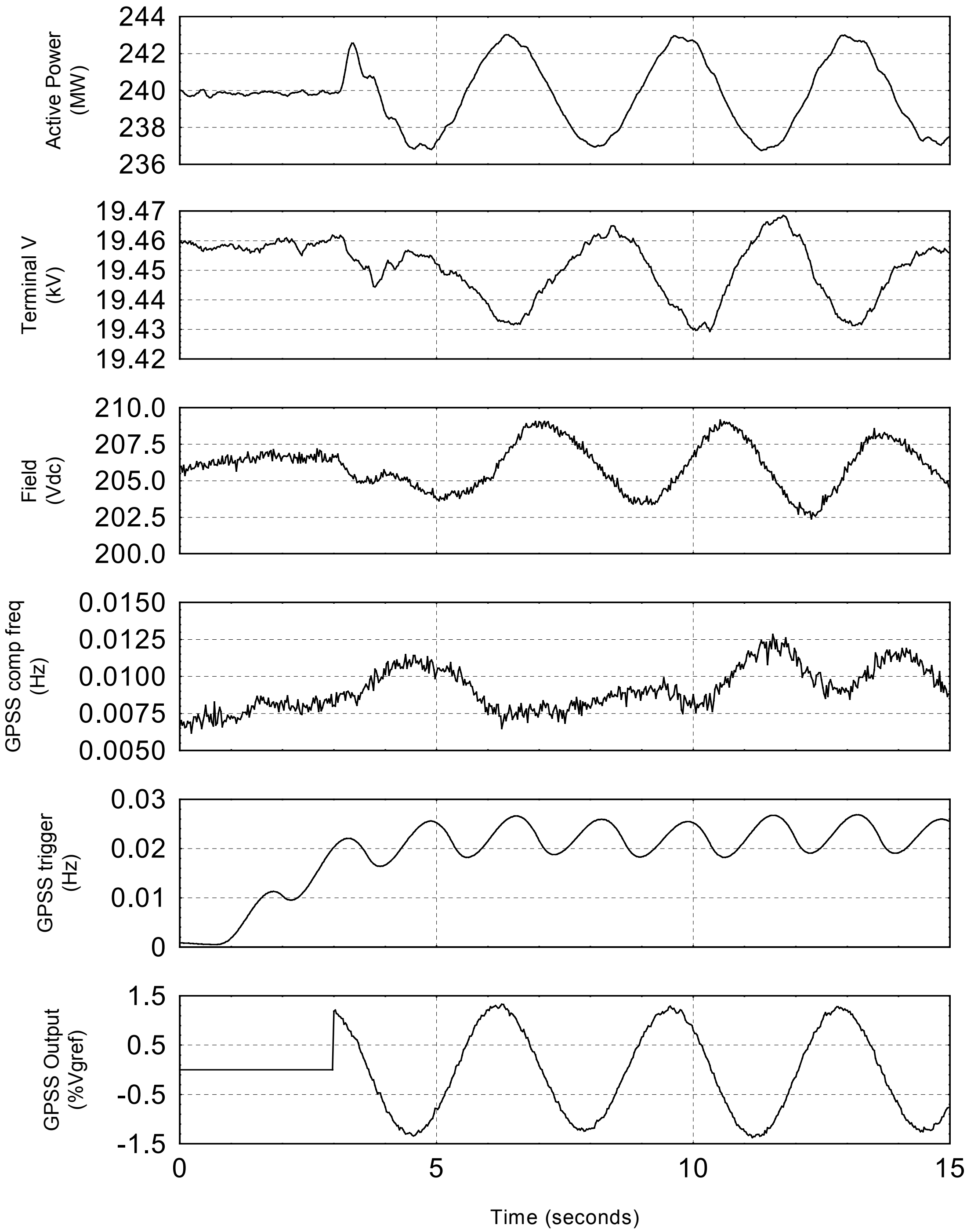


Figure C12. Alamitos Tests – GPSS Closed-Loop Operation Test Signal Applied to Frequency Input, Ks = -20, 02/12/98

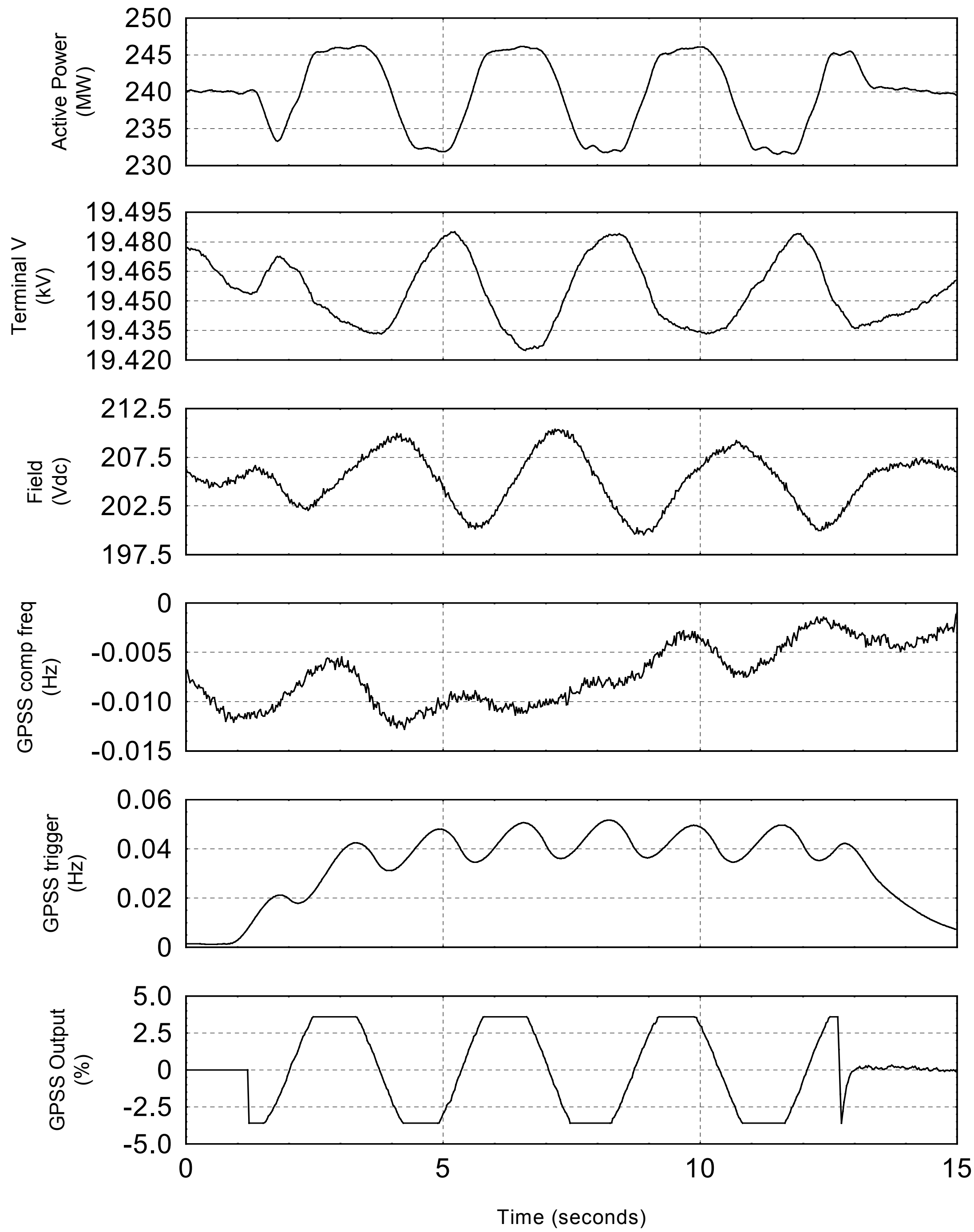


Figure C13. Alamitos Tests – GPSS Closed-Loop Operation Test Signal Applied to Frequency Input, Ks = -40, 02/12/98

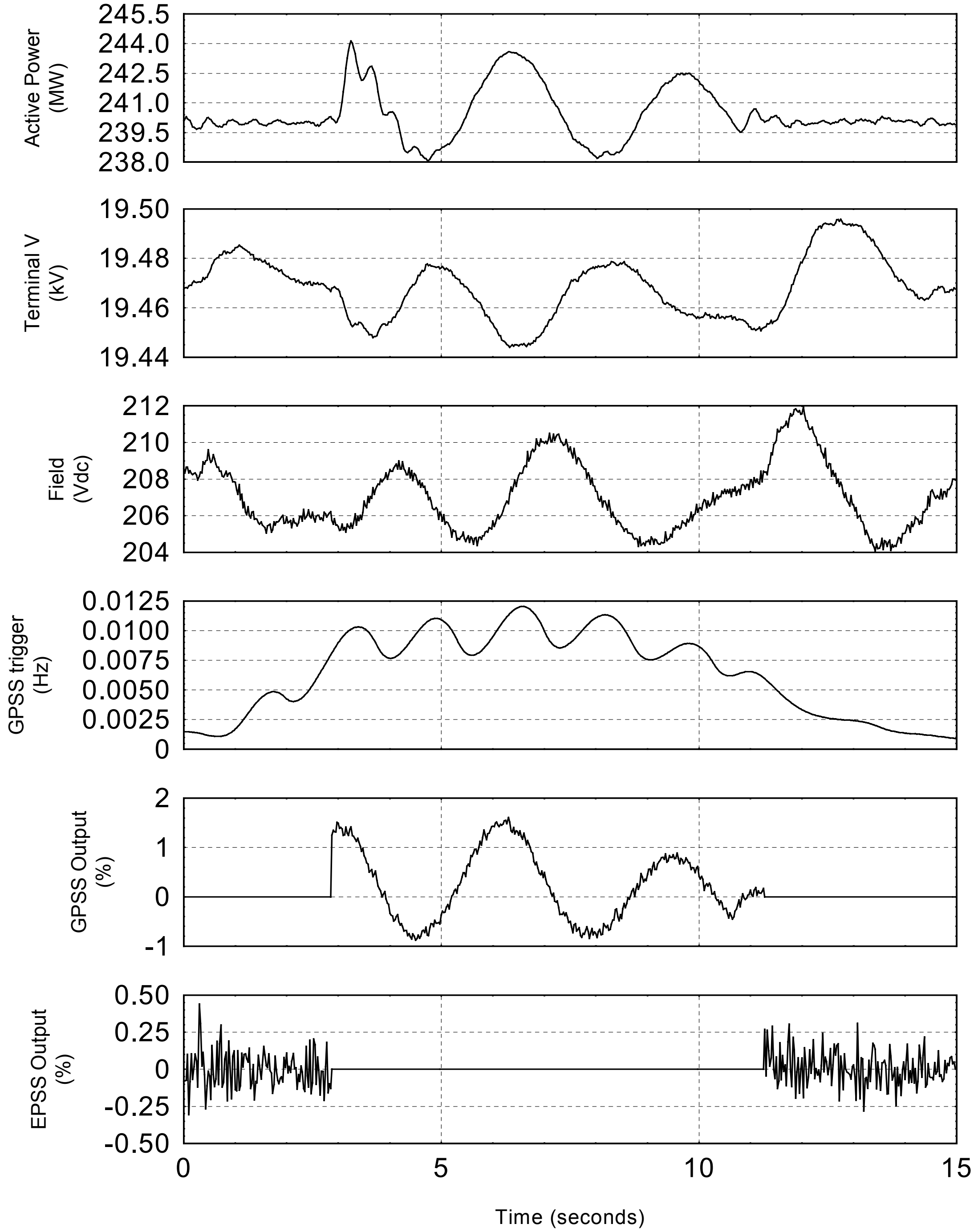


Figure C14. Alamitos Tests – GPSS/EPSS Test Low-Frequency Test Trigger, 12/02/98

Appendix IV
Site Test Plan
Alamitos Unit 5, May 18-19, 1999

1.0 Inspection of Hardware and Wiring

Unit Conditions – Generators' load levels (not critical). EPSS disconnected from LP unit exciter, IPSS disconnected from HP unit exciter and governor.

	Description	Result
1	Check that hardware modifications have been made to both the IPSS and EPSS (refer to list transmitted to T. Eberly 11/12/97). Inspect each unit for possible damage caused during transit.	Done 12/16/97 (Performed during Unit 6 commissioning.)
2	Check connection of PT and CT input modules (PSS3 and PSS1) via isolating switches.	Done 3/26/99
3	Check connection of field voltage transducer output to PSS5 module input.	Done 3/26/99
4	Check connection of "EPSS on/off" contact (output #1, PSS13) to station control logic.	Done 3/26/99
5	Check connection of "DPSS trouble" contact (output #2, PSS13) to station control logic.	Done 3/26/99
6	On IPSS unit, check connection of "GPSS on/off" contact (output #4, PSS13) to station control logic.	Done 3/26/99
7	Check connection of "EPSS on/off" input (input #2, PSS11) through station logic.	Done 3/26/99
8	On IPSS unit, check connection of "GPSS on/off" input (input #3, PSS11) through station logic.	Done 3/26/99
9	Check connection of EPSS output (PSS9-2 card on EPSS unit and PSS9B card on IPSS) to external relay logic and voltage regulator control winding.	Done 3/26/99
10	Check connection of GPSS output to governor valve control logic.	Inserting 499K as R20 PSS9B 12/17/97.

2.0 Software Loading/Verification

Unit Conditions – Generators' load levels (not critical). EPSS disconnected from LP unit exciter, IPSS disconnected from HP unit exciter and governor.

	Description	Result
1	Connect RS232 to EPSS unit. Apply ac power to unit and connect portable computer for communication. Confirm that unit is functioning. Halt DPSS unit through software.	Done 2/11/98
2	Turn off ac supply, remove processor card and disconnect battery. Short terminals to clear battery-backed memory. Replace battery. Re-install processor card and apply ac power.	Not necessary, upload performed without this step.
3	Upload new program and configuration file to FLASH EEPROM.	Done 2/11/99 Uploaded final program from Unit 6.
4	Load Host software and check for correct operation and version numbers (under Help menu).	Done Host V2R9, DPSS V4R3. Modified to DPSS V4R4 to correct test signal problem.
5	Enter each menu and modify settings as required to the starting values.	Done 5/18/99
6	Repeat steps 1 through 5 for IPSS on HP unit.	Done 5/18/99, loaded with V4R4.

3.0 Preparation/Off-line Measurements

Unit Conditions – Exciters energized. Generators' load levels not critical.

	Description	Result
1	Measure power supply outputs on EPSS.	Done 3/26/99
2	Check for alarms or any other indications of problems.	Done 3/26/99
3	Check operation of remote status inputs from control room.	Done 3/26/99
4	Test contact outputs using host program, and check local alarms in control room.	Done 3/26/99
5	Repeat steps 1 through 4 for IPSS.	Done 3/26/99

4.0 Exciter Tuning LP Unit

Unit Conditions – LP exciter energized on AVR control, generator at rated terminal voltage. HP exciter on MANUAL control for part of the tests.

	Description	Result
1	Verify PT input signals and test points on EPSS printed circuit board.	Done 3/26/99
2	Check calculated voltage and frequency quantities.	Done 3/26/99
3	Apply CT input signals to the EPSS and compare readings with available meters.	Done 3/26/99
4	Turn EPSS gain to zero, and place EPSS in-service by enabling all hardware and software switches. Monitor exciter quantities and terminal voltage to ensure that there is no disturbance to the normal operation of the AVR.	Done 5/18/99
5	Switch the HP exciter to MANUAL control. Using DPSS test supply, inject small voltage change and measure resulting terminal voltage change. Calibrate EPSS software output scaling.	Done 5/18/99
6	Using software test facility, apply 1% terminal voltage reference step into exciter AVR control winding. Measure resulting exciter and generator output changes on the stabilizer data recorder and external direct-writing recorder.	Done 5/18/99
7	Measure signal on field voltage transducer output (modify calibration if necessary).	Done 5/18/99
8	Examine overall closed-loop voltage regulator response. Switch LP unit exciter to MANUAL. Adjust the AVR gain (decrease R1), the damping panel gain (decrease R7) and the damping time constant (decrease R8) to achieve the recommended values.	Done 3/26/99
9	Disconnect the damping panel input and measure the transfer function. Compare with calculated values for the recommended settings and adjust as required. Once complete, restore normal connections.	Not performed, adjusted similar to Unit 6.
10	Transfer LP unit back to AVR control, and perform step response measurement (step 6). Compare measured response with simulations of recommended settings. If response appears to match desired level, continue on to next step. If not, repeat steps 8, 9, and 10 until desired response is achieved.	Done 5/18/99
11	Perform measurement of closed-loop voltage regulator transfer function. Compare response with simulation of recommended settings, and the EPSS tuning data. If a good match exists, continue to next step. If the response does not match, repeat steps 9 and 10 until an adequate match is obtained	Done 5/18/99

5.0 Exciter Tuning HP Unit

Unit Conditions – HP exciter energized on AVR control, generator at rated terminal voltage. LP exciter on MANUAL control for part of the tests.

	Description	Result
1	Verify PT input signals and test points on IPSS printed circuit board.	Done 5/19/99
2	Check calculated voltage and frequency quantities.	Done 5/19/99
3	Apply CT input signals to the IPSS and compare readings with available meters.	Done 5/19/99
4	Turn EPSS/GPSS gain to zero. Disconnect GPSS output signal to governor valve control. Place EPSS in-service by enabling all hardware and software switches. Monitor exciter quantities and terminal voltage to ensure that there is no disturbance to the normal operation of the AVR.	Done 5/19/99
5	Switch the LP exciter to MANUAL control. Using the software test supply, inject small voltage change and measure resulting terminal voltage change. Calibrate EPSS software output scaling.	Done 5/19/99
6	Using software test facility, apply 1% terminal voltage reference step into exciter AVR control winding. Measure resulting exciter and generator output changes on the stabilizer data recorder and external direct-writing recorder.	Done 5/19/99
7	Measure signal on field voltage transducer output (modify calibration if necessary).	Done 5/19/99
8	Examine overall closed-loop voltage regulator response. Switch HP unit exciter to MANUAL. Adjust the AVR gain (decrease R1), the damping panel gain (decrease R7) and the damping time constant (decrease R8) to achieve the recommended values.	Not performed based on results obtained for Unit 6.
9	Disconnect the damping panel input and measure the transfer function. Compare with calculated values for the recommended settings and adjust as required. Once complete, restore normal connections.	Not done based on results obtained on LP unit.
10	Transfer HP unit back to AVR control, and perform step response measurement (step 6). Compare measured response with simulations of recommended settings. If response appears to match desired level, continue on to next step. If not, repeat steps 8, 9, and 10 until desired response is achieved.	Done 5/19/99
11	Perform measurement of closed-loop voltage regulator transfer function. Compare response with simulation of recommended settings, and the EPSS tuning data. If a good match exists, continue to next step. If the response does not match, repeat steps 9 and 10 until an adequate match is obtained.	Done 5/19/99
12	Restore both units to AVR control. Repeat step response measurement and record overall response. Examine the reactive power changes and adjust reactive compensation if necessary.	Done 5/19/99

6.0 LP Excitation Stabilizer Measurements

Unit Conditions – HP and LP units running at high load (>70 percent nameplate MVA), exciters on AVR control.

	Description	Result
1	On LP unit, perform on-line step disturbance test with EPSS gain set to zero. Download captured data record and examine the calculated quantities.	Done 5/18/99
2	Increase EPSS gain to 1/10 of recommended setting and repeat the measurement. Gradually increase EPSS gain while monitoring output continuously on direct-writing recorder. Perform measurement at recommended gain.	Done 5/18/99
3	Perform long-term recording, to determine effect on terminal voltage and other output quantities.	Done 5/18/99
4	Increase gain until signs of an exciter mode, or double the recommended gain is achieved.	Done 5/18/99
5	Reduce the gain to the rated level and reduce the unit's excitation as much as is allowable by system and plant constraints. Repeat step response measurement.	Done 5/18/99

7.0 HP Excitation Stabilizer Measurements

Unit Conditions – HP and LP units running at high load (>70 percent nameplate MVA), exciters on AVR control.

	Description	Result
1	On HP unit, perform on-line step disturbance test with EPSS gain set to zero. Download captured data record and examine the calculated quantities.	Converted EPSS to frequency-based design due to extreme levels of phase lead required. Used original settings from the Westinghouse PSS.
2	Increase EPSS gain to 1/10 of recommended setting and repeat the measurement. Gradually increase EPSS gain while monitoring output continuously on direct-writing recorder. Perform measurement at recommended gain.	Done 5/19/99
3	Perform long-term recording, to determine effect on terminal voltage and other output quantities.	Done 5/19/99
4	Increase gain until signs of an exciter mode, or double the recommended gain is achieved.	Done 5/19/99
5	Reduce the gain to the rated level and reduce the unit's excitation as much as is allowable by system and plant constraints. Repeat step response measurement.	Done 5/19/99

8.0 HP Governor Stabilizer Measurements

Unit Conditions – HP and LP units running at high load (>70 percent nameplate MVA), exciters on AVR control.

	Description	Result
1	Turn GPSS gain to zero. Verify that GPSS output is zero. Connect GPSS to governor valve control. Apply small step change in GPSS output and measure the valve position and power output changes on a direct-writing recorder and the stabilizer. Repeat for different modulation sizes. Repeat until 10 MW modulation range is achieved. Calibrate the GPSS output ratio and output limits.	Done 5/19/99, checked for output control, settings based on results of Unit 6.
2	Disconnect the GPSS from the governor valve control and perform a transfer function measurement of the valve control input versus active power. Compare with previously submitted results and GPSS phase compensation selection.	Performed previously.
3	Set the GPSS settings to the original selections. Monitor the GPSS output and other quantities using the data recorder during ambient operation. Record quantities such as background oscillation levels, GPSS trigger algorithm output, compensated frequency signal output, and GPSS output. Perform both time and frequency-domain measurements of the various quantities. Measure background torsional oscillation components in various signals.	Done 5/19/99
4	Turn the EPSS functions off on both the EPSS and IPSS units. Connect the GPSS output to the governor valve control input. Place the GPSS in-service with a low-trigger threshold level and perform on-line monitoring for an extended period.	Done 5/19/99
5	Inject a 0.3 Hz input signal in the computed frequency input for a few cycles and measure the governor valve and unit responses. Examine data record and adjust settings if necessary. Repeat for longer time duration and capture data record. Repeat analysis.	Done 5/19/99, found GPSS output blocked in SOLO mode. OK in Dual mode.
6	Place the EPSS unit in-service on the HP unit and repeat step 5. Be prepared to turn off the control if coordination problems exist. Based on the results of this test, determine the correct operating mode.	Using Dual mode.
7	Place the EPSS in-service on the LP unit and repeat step 5.	Done 5/19/99
8	Adjust settings to proposed in-service levels and perform long-term monitoring of various quantities.	Done 5/19/99
9	Select quantities to be recorded on internal data logger and set auto-triggers to capture data records which could potentially trigger the GPSS function.	Done 5/19/99

Appendix V
Selected Site Test Results of Alamitos Unit 5

Figure B1

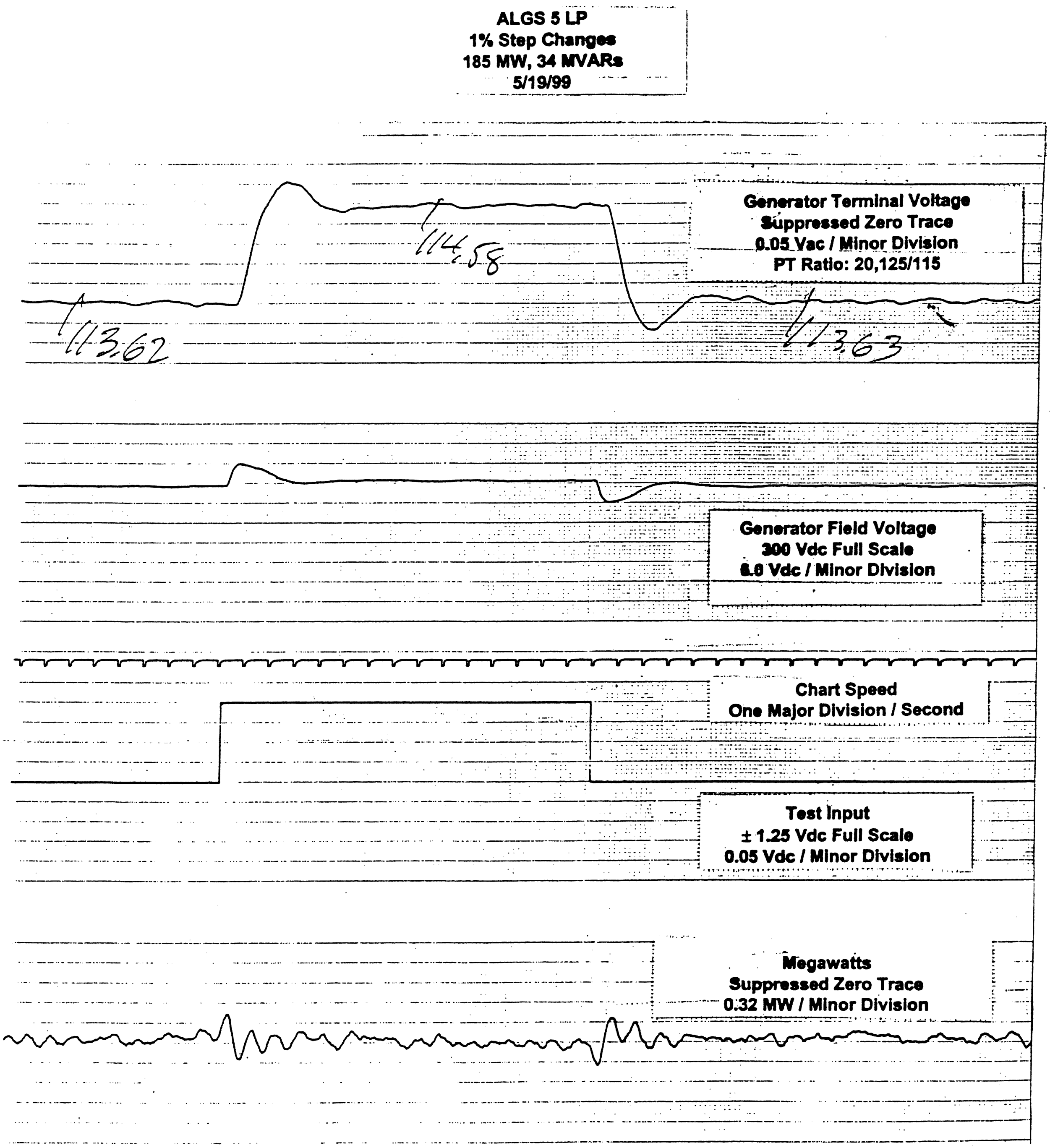
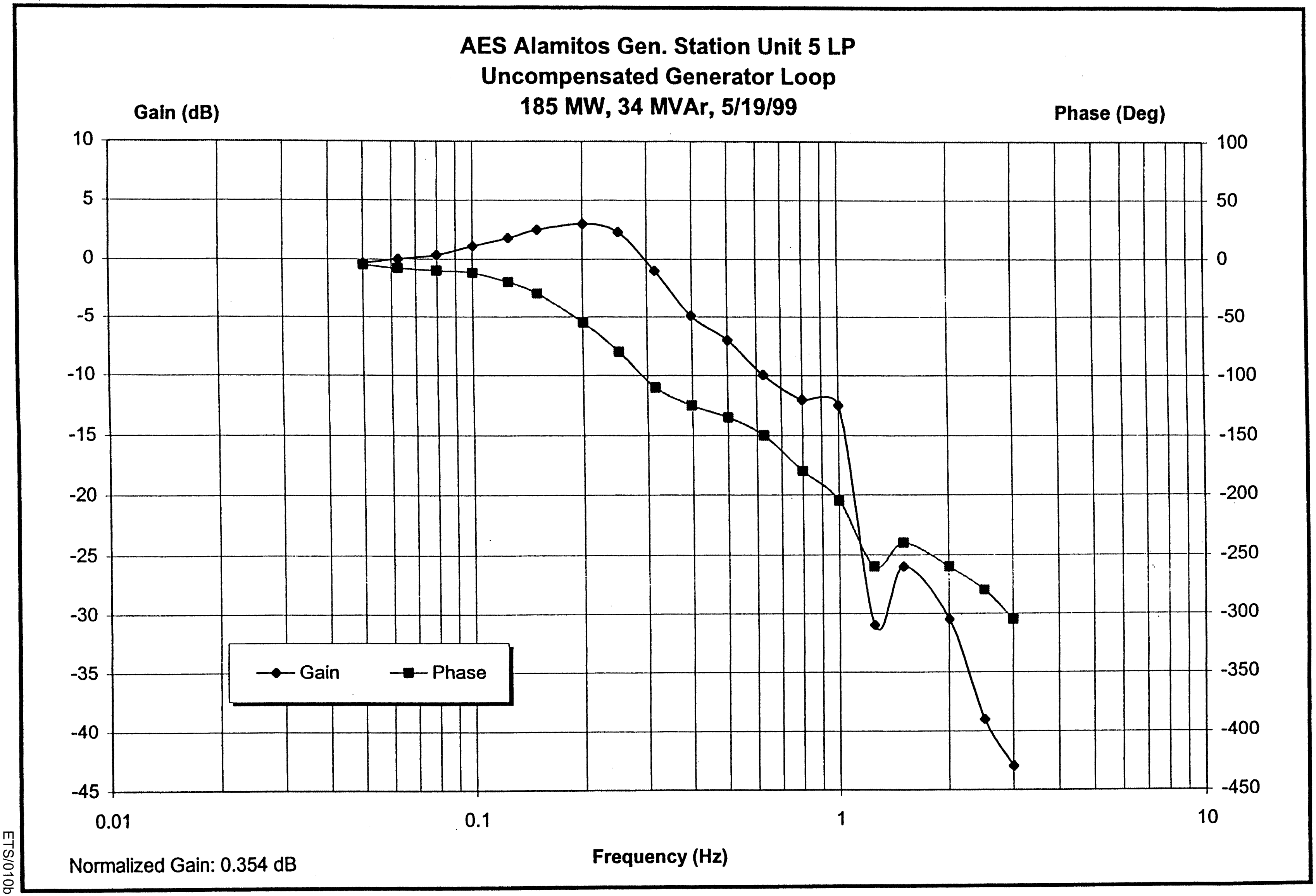
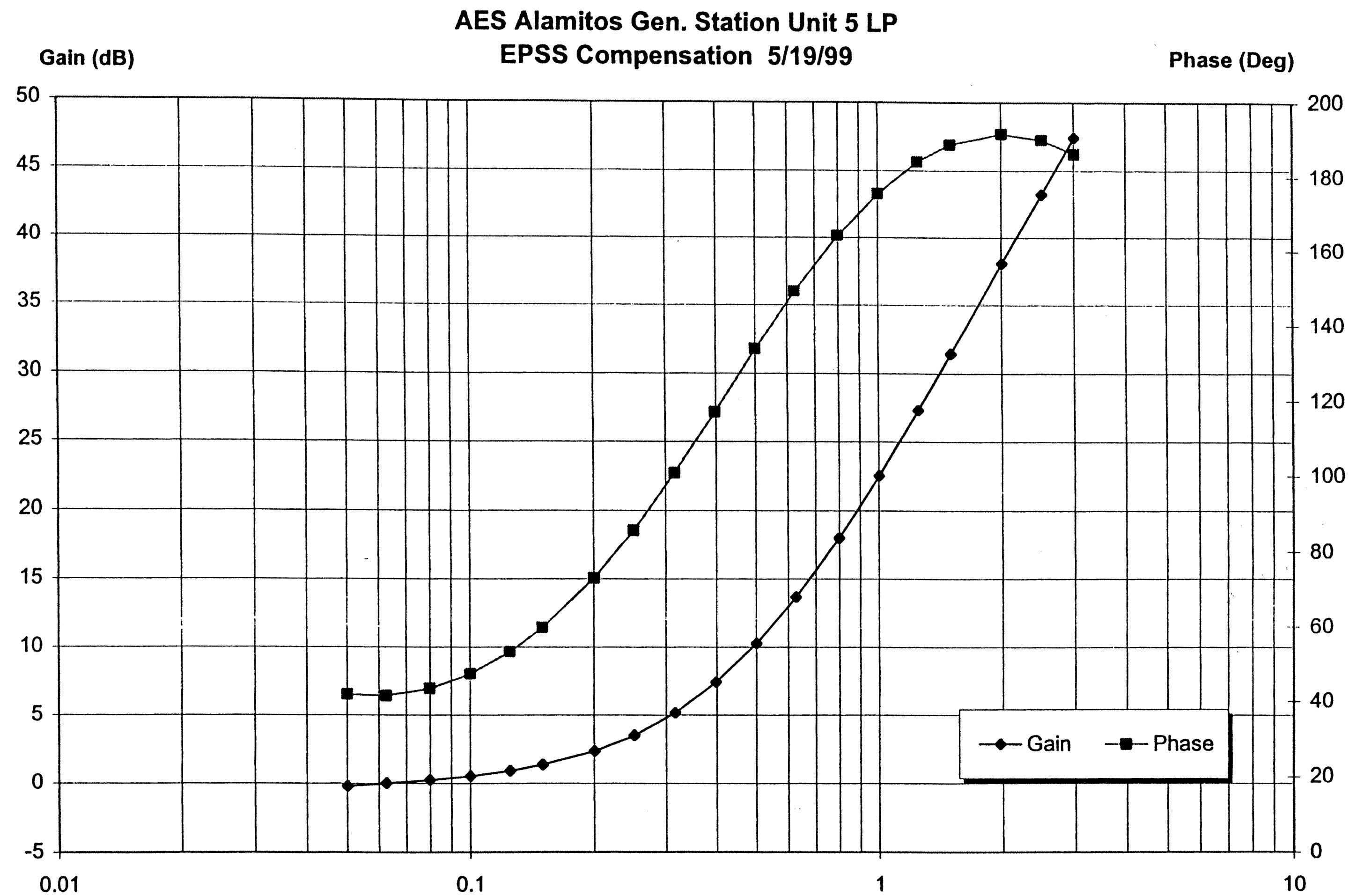

ALGS 5 LP
1% Step Changes
185 MW, 34 MVARs
5/19/99
Generator Terminal Voltage
Suppressed Zero Trace
0.05 Vac / Minor Division
PT Ratio: 20,125/115
113.62
114.58
113.63
Generator Field Voltage
300 Vdc Full Scale
6.0 Vdc / Minor Division
Chart Speed
One Major Division / Second
Test Input
± 1.25 Vdc Full Scale
0.05 Vdc / Minor Division
Megawatts
Suppressed Zero Trace
0.32 MW / Minor Division

Figure B2



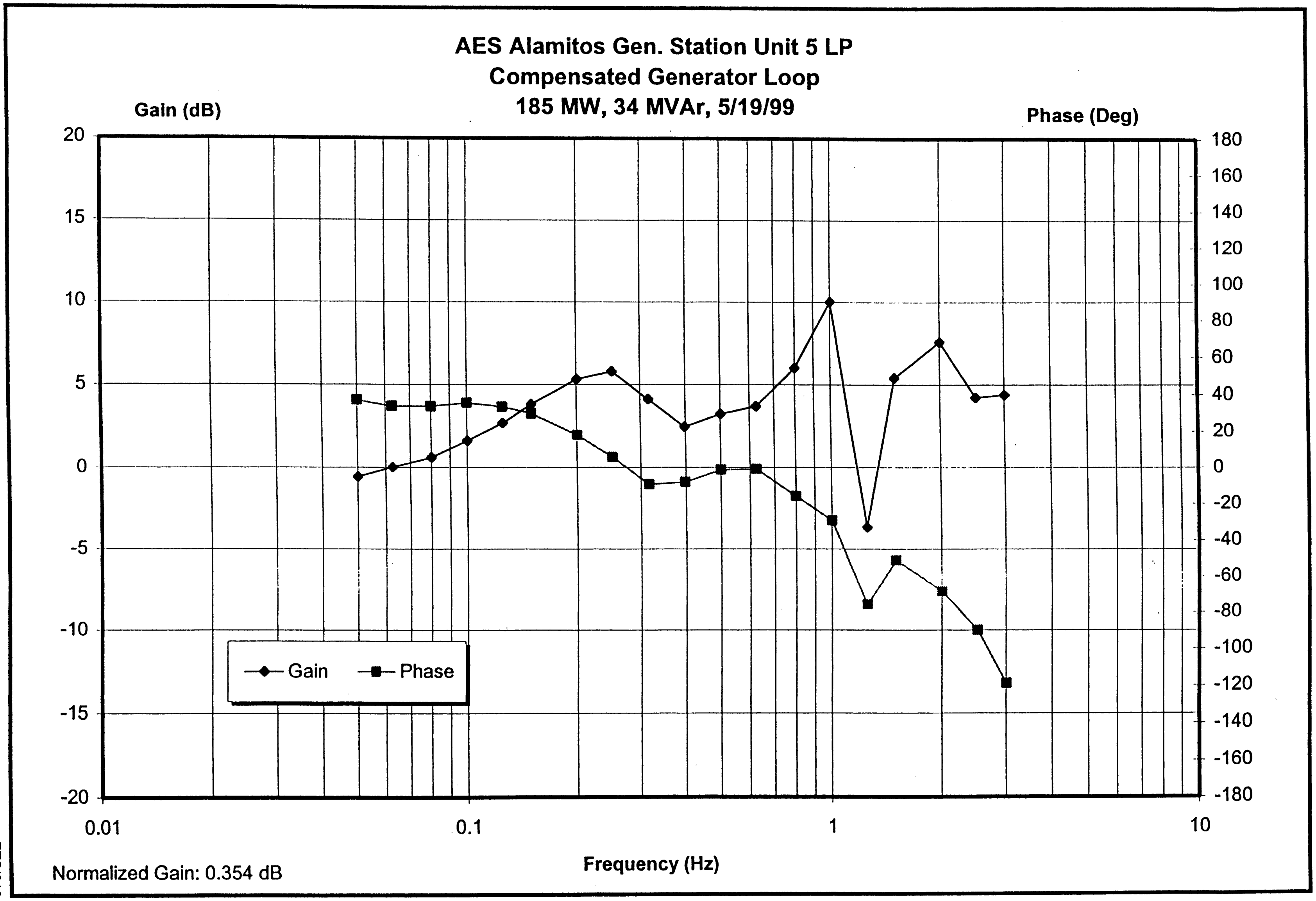
ETS/010b

Figure B3



Reset TC = 15s, Lead TC = 0.4s, 0.4s, 0.25s
Lag TC = 0.02s, 0.02s, 0.015s

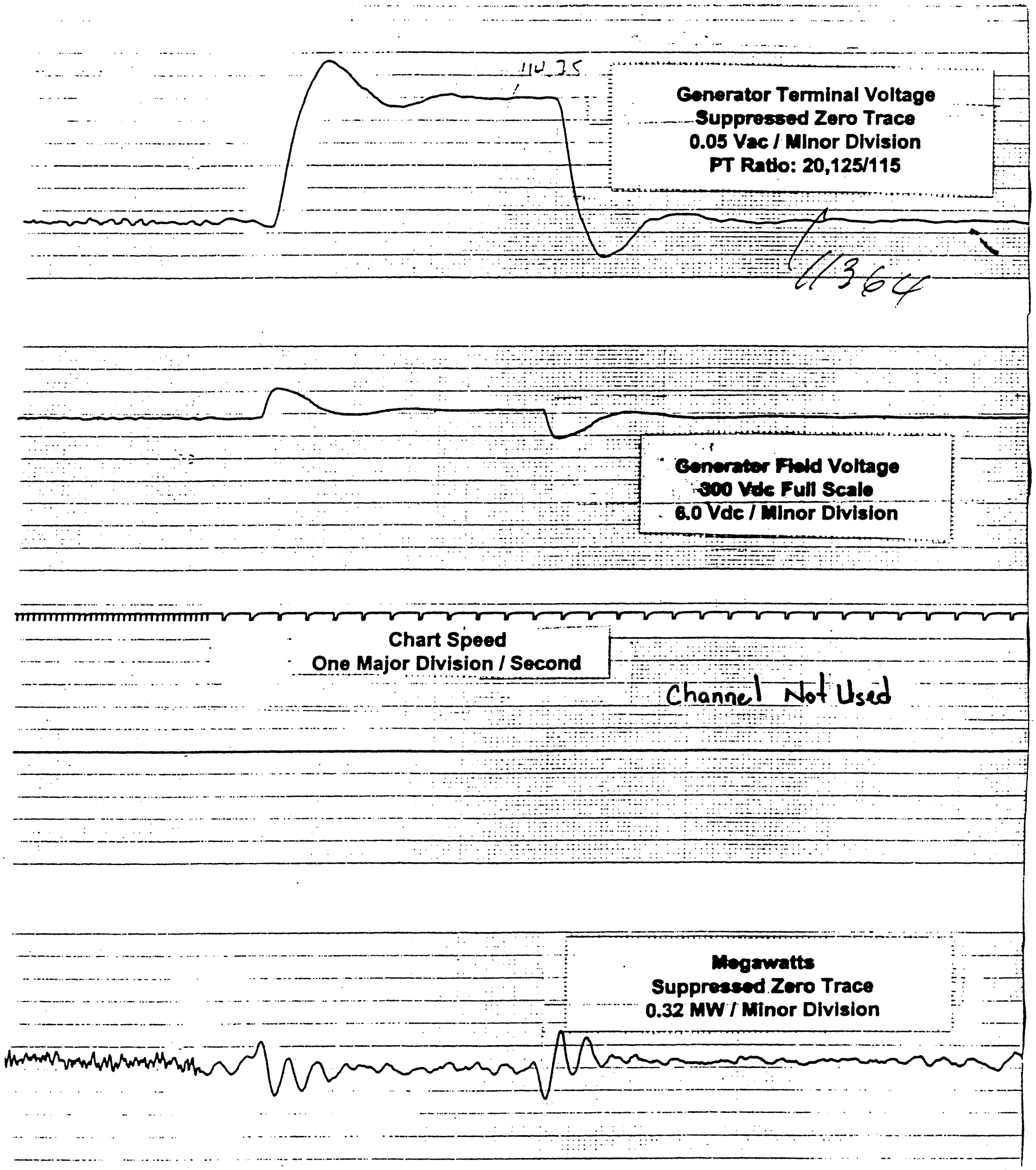
Figure B4



ETS/010d

Figure B5

ALGS 5 LP 5/19/99
1% Step Changes
185 MW, 34 MVARs
EPSS Gain = 0



ETS/010e

Figure B6

ALGS 5 LP 5/19/99
1% Step Changes
185 MW, 34 MVARs
EPSS Gain = 5

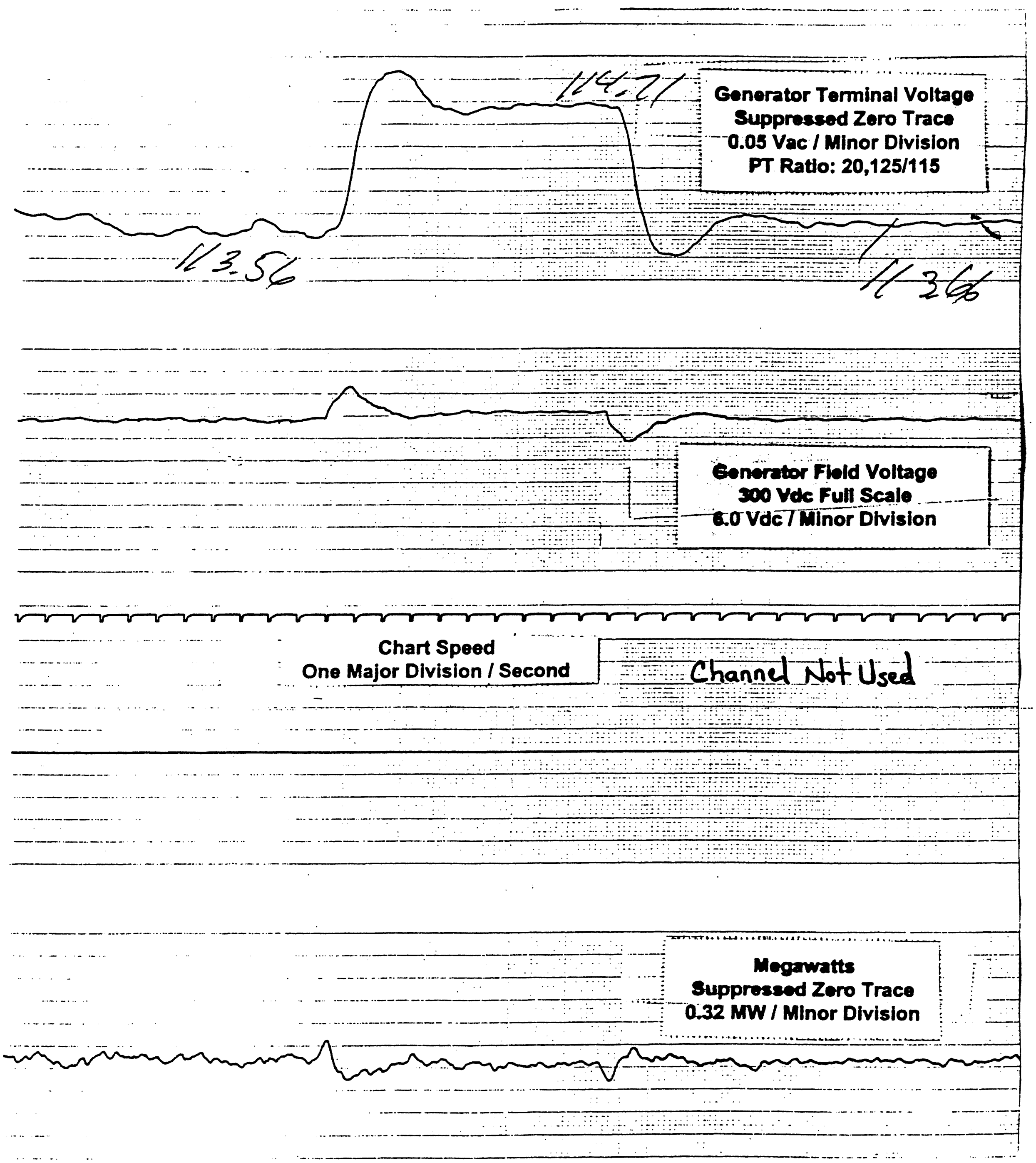


Figure B7

ALGS 5 HP
1% Step Changes
196 MW, 44 MVARs
5/19/99

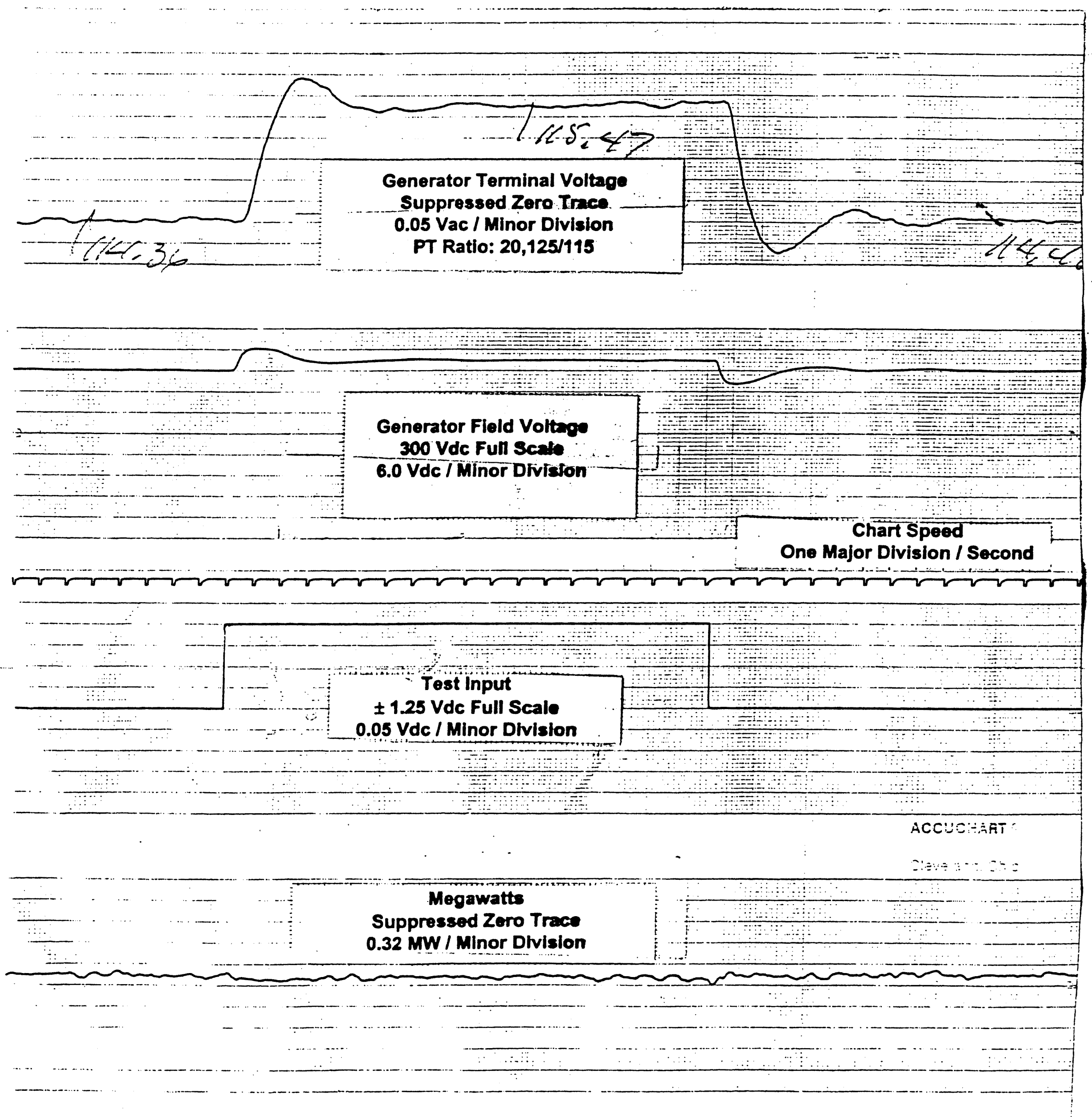
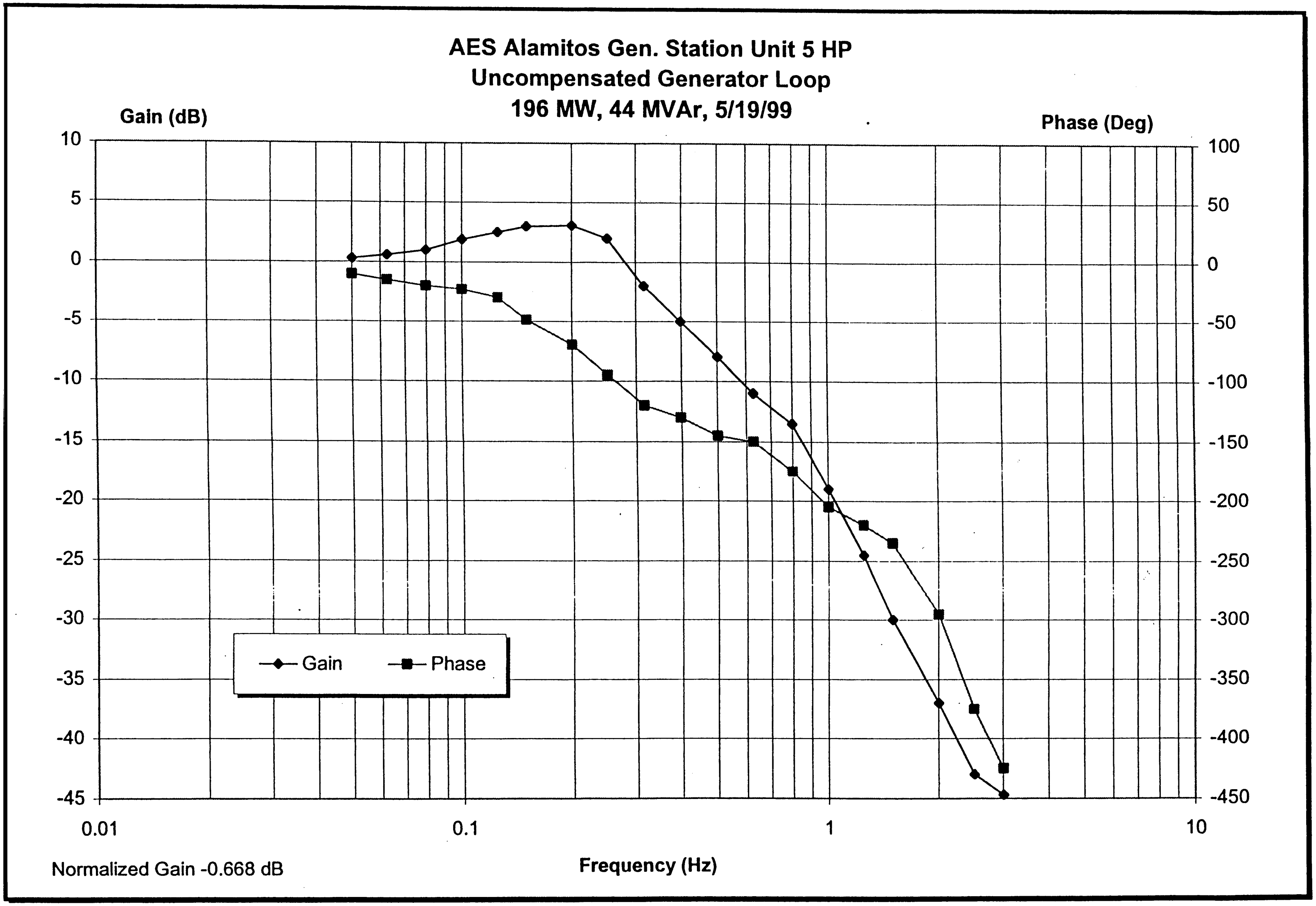


Figure B8



ETS/010h

Figure B9

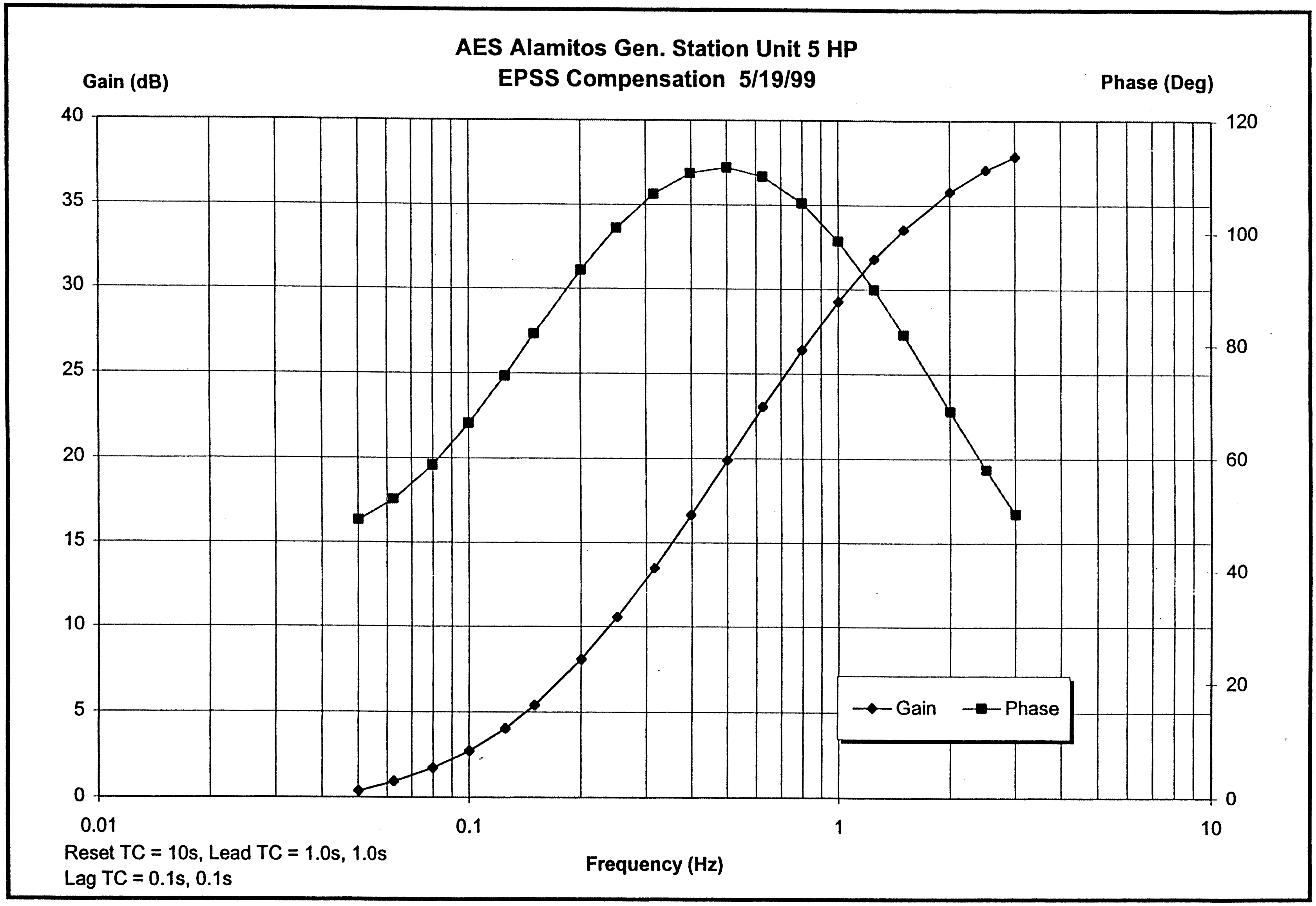
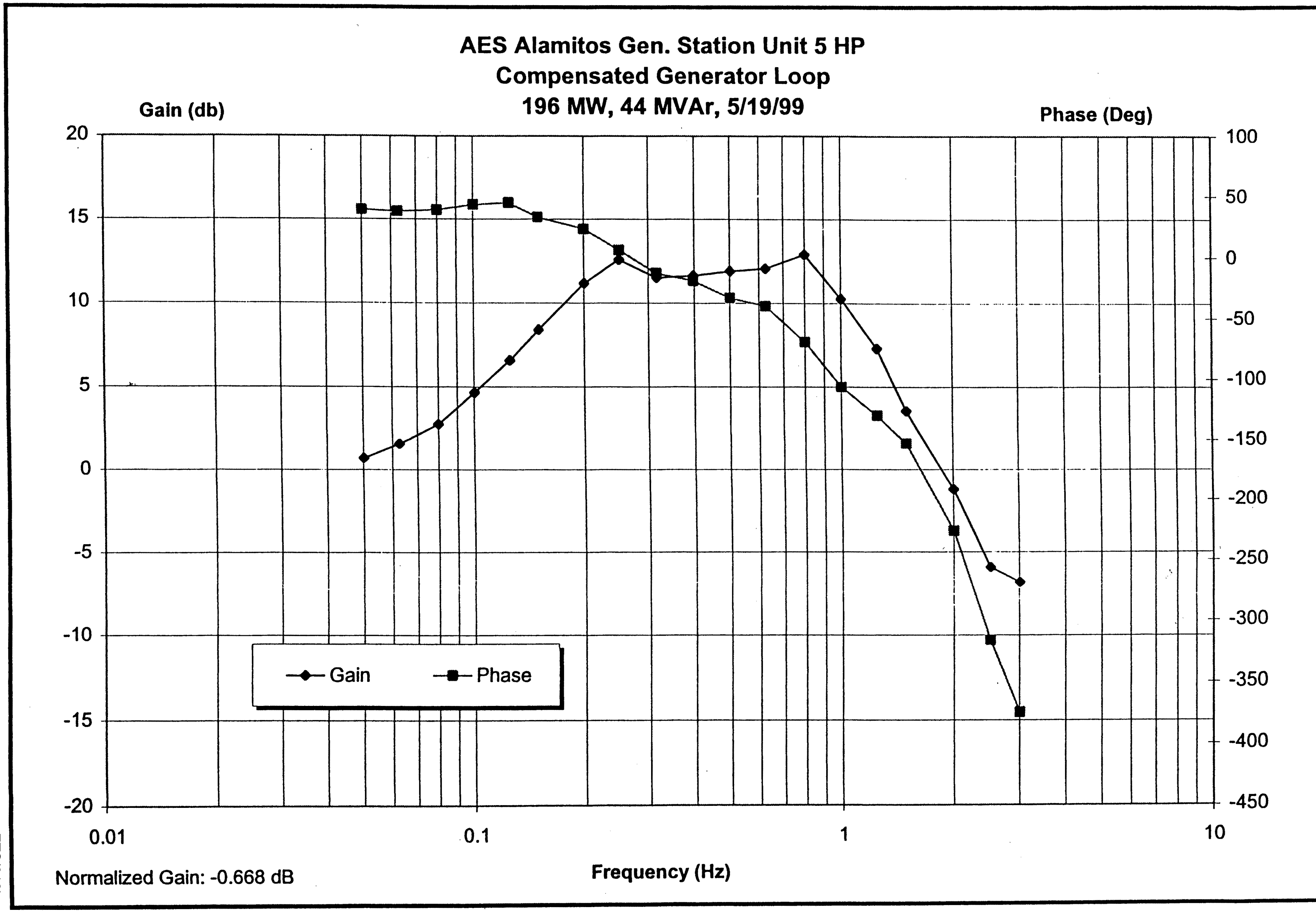

AES Alamitos Gen. Station Unit 5 HP
EPSS Compensation 5/19/99
Gain (dB)
Phase (Deg)
40
35
30
25
20
15
10
5
0
120
100
80
60
40
20
0
0.01
0.1
1
10
Frequency (Hz)
Gain
Phase
Reset TC = 10s, Lead TC = 1.0s, 1.0s
Lag TC = 0.1s, 0.1s

Figure B10



ETS/010j

Figure B11

ALGS 5 HP 5/19/99
1% Step Changes
196 MW, 44 MVARs
EPSS Gain = 0

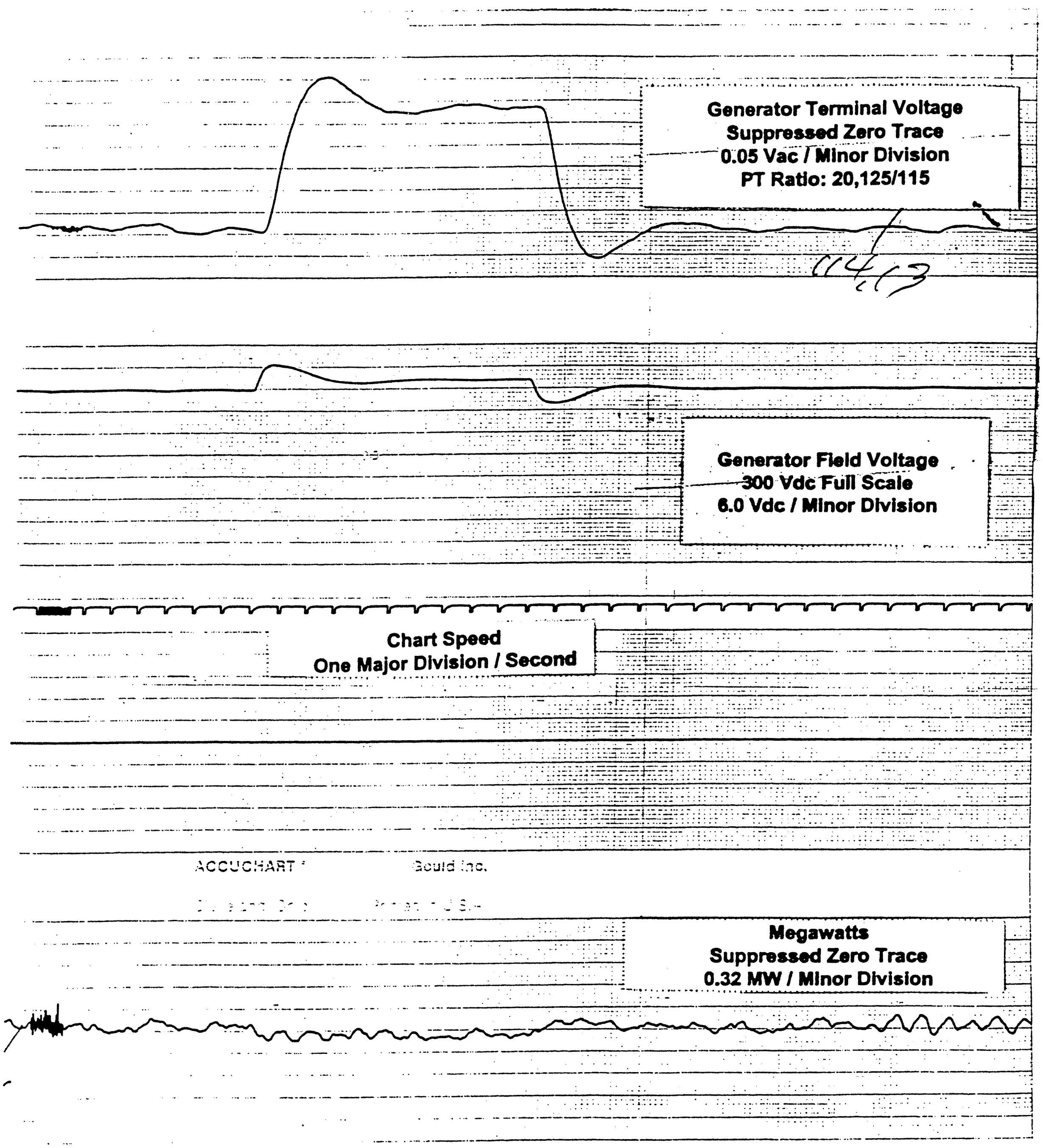


Figure B12

ALGS 5 HP 5/19/99
1% Step Changes
196 MW, 44 MVARs
EPSS Gain = 2

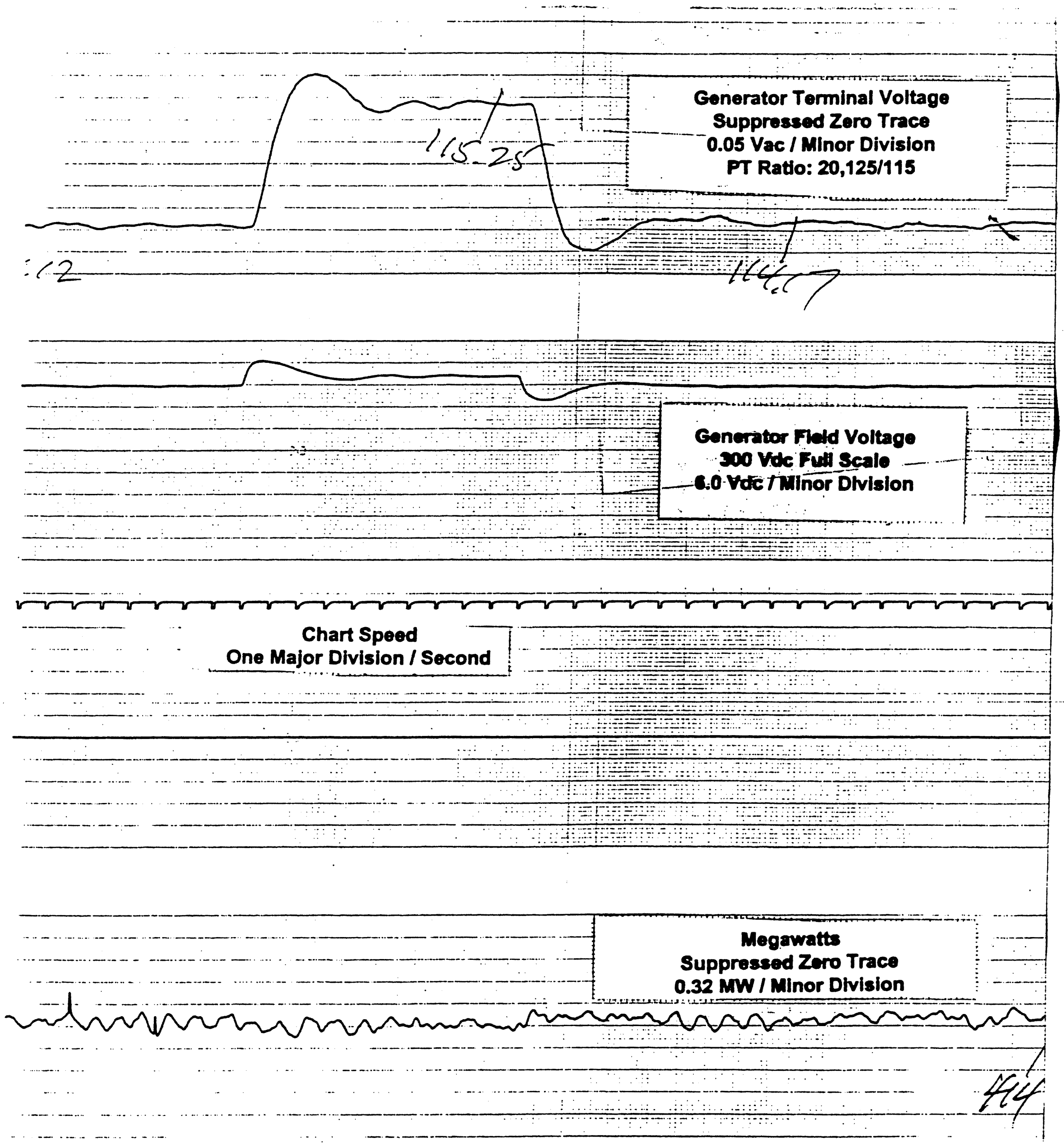
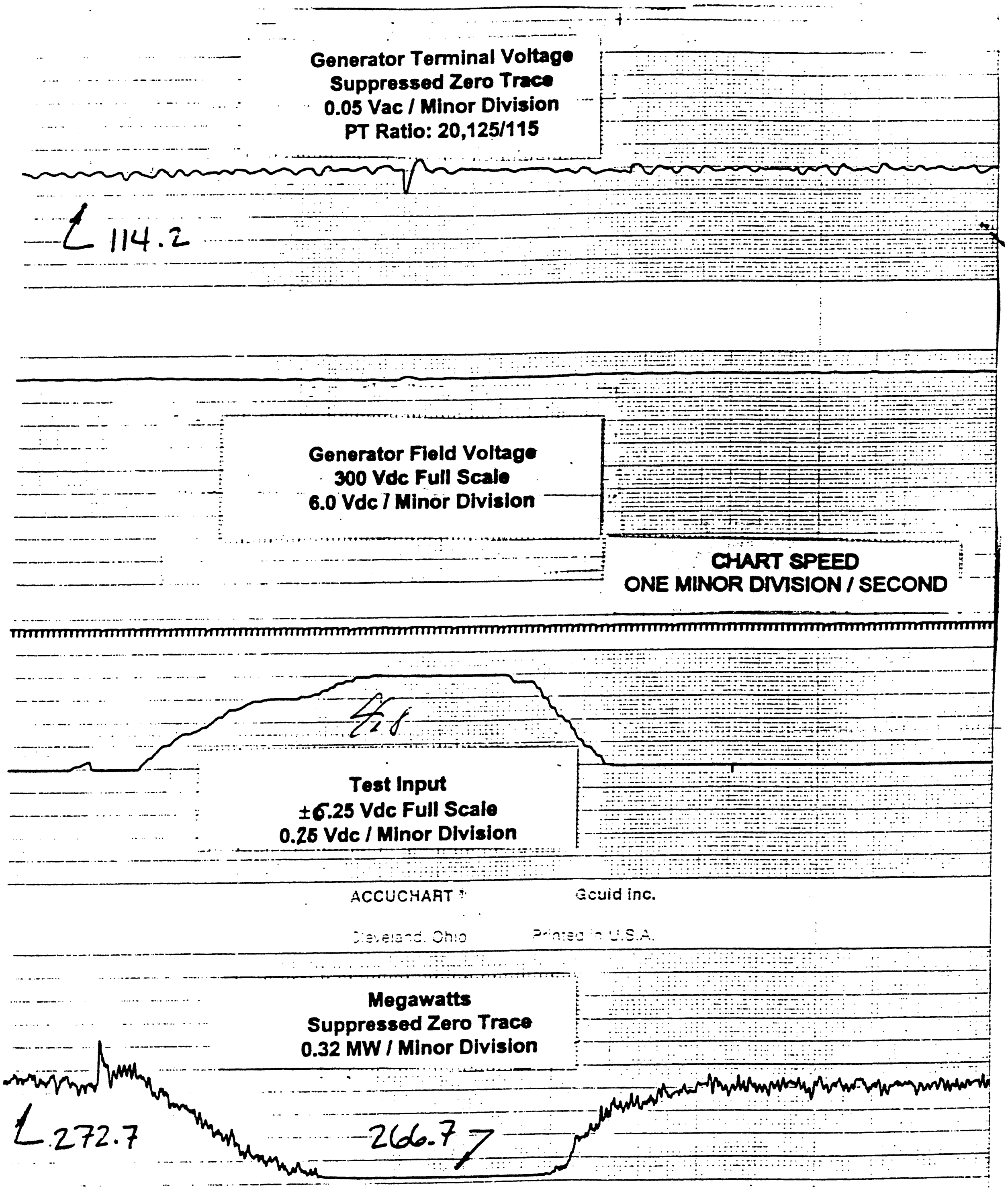


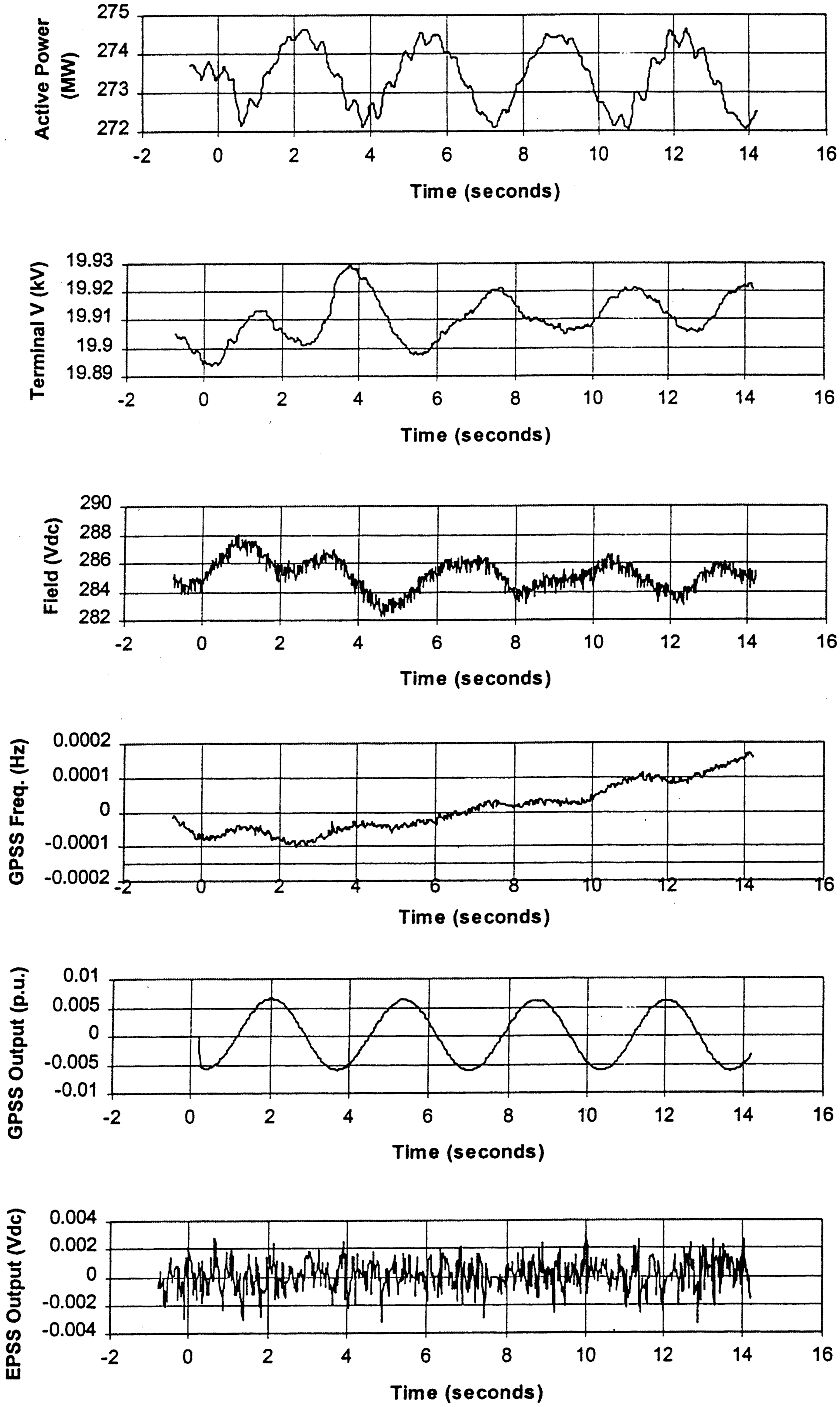
Figure B13

ALGS 5 HP
Governor Valve Modulation
196 MW, 44 MVARs
5/19/99



ETS/010m

Figure B14


Active Power (MW)
275
274
273
272
-2 0 2 4 6 8 10 12 14 16
Time (seconds)
Terminal V (kV)
19.93
19.92
19.91
19.9
19.89
-2 0 2 4 6 8 10 12 14 16
Time (seconds)
Field (Vdc)
290
288
286
284
282
-2 0 2 4 6 8 10 12 14 16
Time (seconds)
GPSS Freq. (Hz)
0.0002
0.0001
0
-0.0001
-0.0002
-2 0 2 4 6 8 10 12 14 16
Time (seconds)
GPSS Output (p.u.)
0.01
0.005
0
-0.005
-0.01
-2 0 2 4 6 8 10 12 14 16
Time (seconds)
EPSS Output (Vdc)
0.004
0.002
0
-0.002
-0.004
-2 0 2 4 6 8 10 12 14 16
Time (seconds)

Appendix VI
Data Collected for Unit 6 After 3/3/98

Unit: 6
Date of Work: 3/3/98 – 1/22/99

Brief Description of Work Performed

The new integrated power system stabilizer (IPSS) installed on Unit 6 at AES Alamitos Generating station has been collecting data from 3/3/98. ESI engineering personnel have downloaded data on three different occasions. Charts of selected data are included in the attachments to this report. The electrical power system stabilizer (EPSS) portion of the IPSS for both the HP and LP generators have triggered numerous data records. The governor power system stabilizer (GPSS) portion of the IPSS on the HP generator has not yet triggered and operated.
The charts include the MW load, the generator terminal voltage, the field voltage, GPSS trigger signal, GPSS output, EPSS sensing frequency, and EPSS output where applicable.

HP GPSS and EPSS Settings

The operating parameters for the GPSS and EPSS as well as the data recorder settings for the HP generator are tabulated below.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~42 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS power-on threshold (p.u. MVA)	0.36	~100 MW
GPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS turn-on frequency (Hz)	0.02	
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	5	0.75 seconds
Number half cycles between logger saves	3	15 second record
Autotrigger Values		
p.u. GPSS Trigger setpoint (Hz)	0.03	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	5	0.04 seconds
Priority	3	
EPSS Output	0.02	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	4	0.033 seconds
Priority	2	

LP EPSS Settings

The operating parameters for the EPSS as well as the data recorder settings for the LP generator are tabulated below.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~33 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~11 MW
GPSS power-on threshold (p.u. MVA)	1.0	No GPSS
GPSS power-on MVA hysteresis (p.u. MVA)	0	
GPSS turn-on frequency (Hz)	0.5	

On/Off Control	Setting	Comment
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	10	1.0 seconds
# half cycles between logger saves	2	10 second record
Autotrigger Values		
EPSS Output	0.03	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	5	0.04 seconds
Priority	2	

Observations

The MW load recorded during the events in January 1999 are all below the trigger threshold of 0.36 p.u. or 100 MW for any GPSS operation. However, during March and October 1998, many of the data records record GPSS trigger frequencies above the 0.02 Hz threshold. In none of these cases did an actual trigger of the GPSS occur. The nominal trigger frequency for these charts also appears to be 0.08 Hz with excursion above and below this value. The manufacturer has been contacted to evaluate the data and a recommendation as to the cause and any recommended setting changes. It may be that the GPSS was not enabled during March and October due to switch problems in the control room. These switches have subsequently been replaced to indicate the enabled state. Additionally, the recorder settings for the data logger have been reset to include 20 half cycles to DELAY or 0.166 seconds to avoid triggering on spikes.

Additional data will be provided each month as more data logger records are downloaded and evaluated.

Attachments (See amended Jan. Report for updated charts)

Appendix 6
Addendum

Unit: 6
Date of Work: 3/3/98 - 1/22/99

January Report Addendum

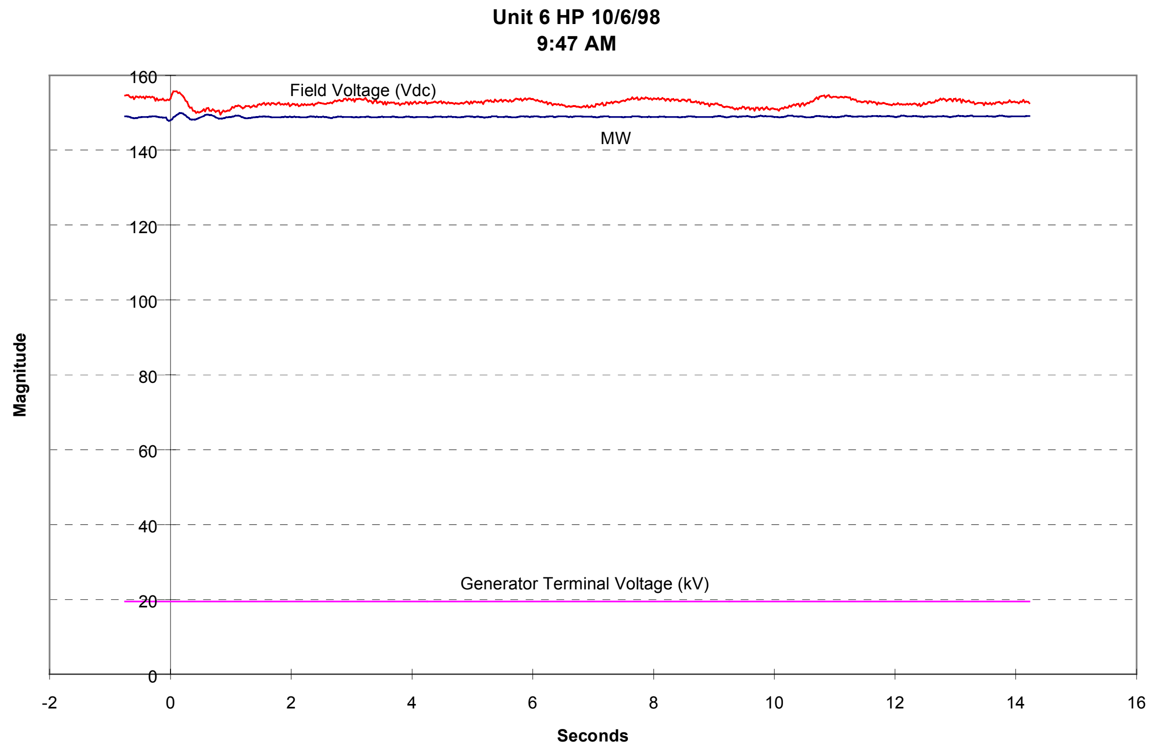
The manufacturer of the equipment was contacted to review the data gathered during the above time period. Raw data files as well as the charts were sent for comparison. The manufacturer noticed discrepancies between the charts and data. The charts had used a multiplier of 80 to obtain the GPSS Trigger Frequency. This multiplier is used internally in the equipment, and the raw data already has been adjusted for this factor of 80. All the charts for the HP unit which depict the GPSS Trigger Frequency are 80 times larger than the actual values.

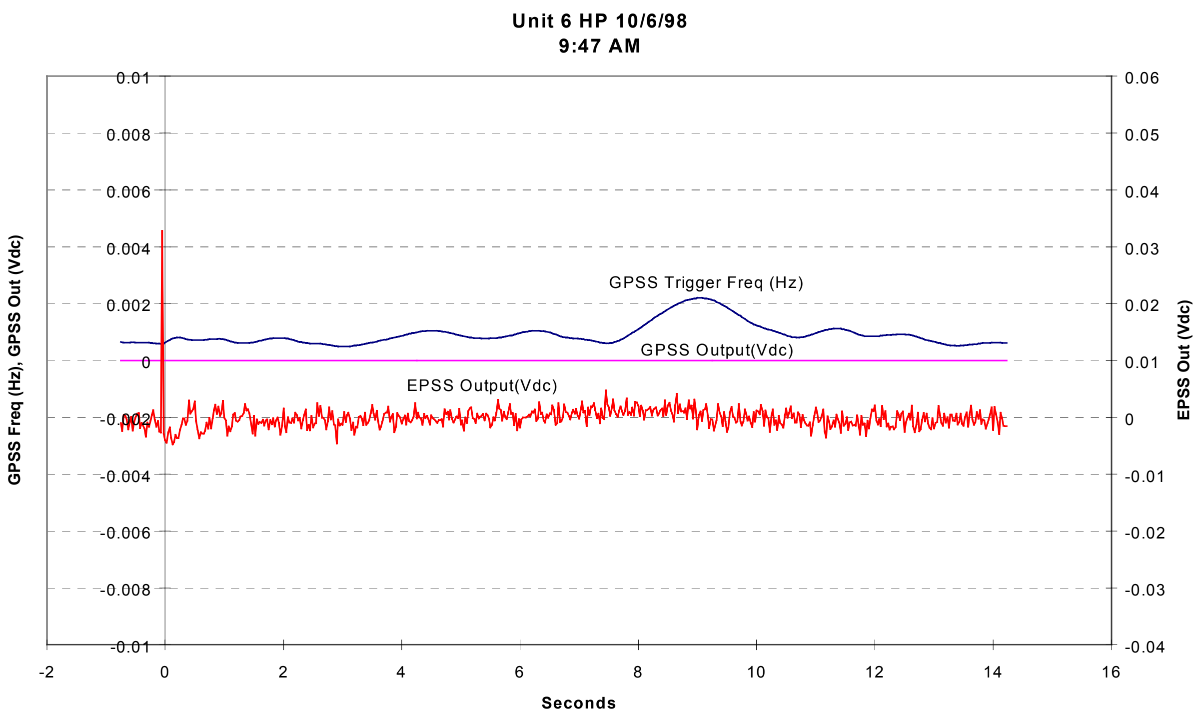
New charts have been created to account for the decrease in GPSS Trigger Frequency magnitude. These are included in this report and should replace the original charts in the January report.

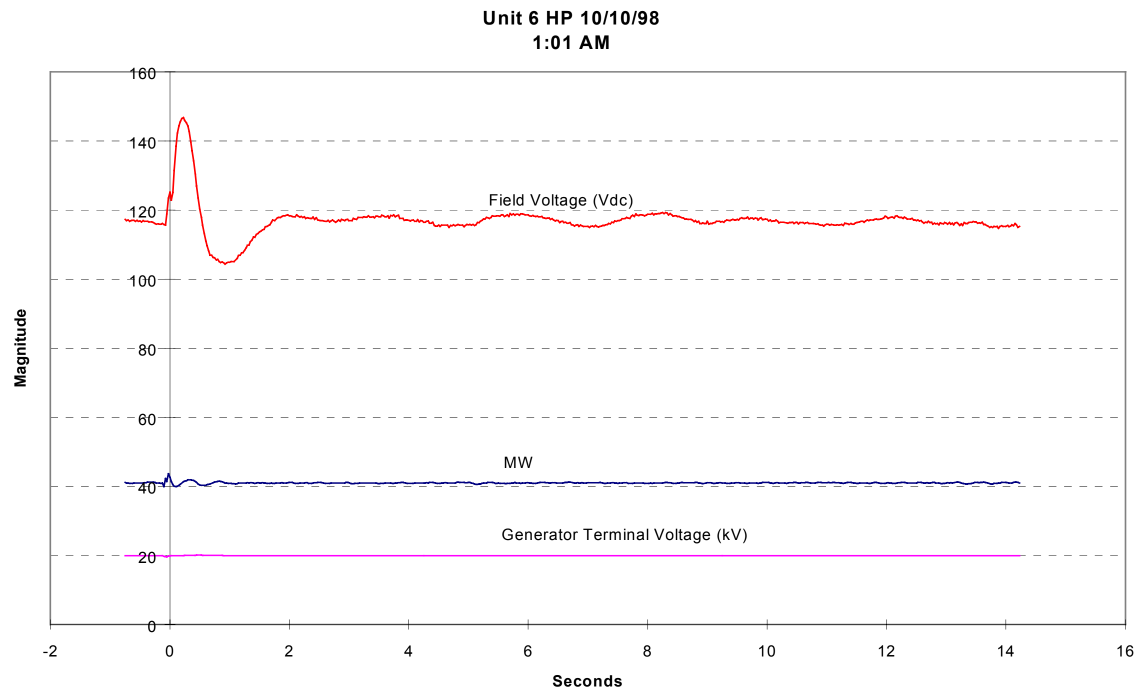
The data recorder trigger level will be reduced in increments until the recorder captures a GPSS trigger event. The actual trigger level of the GPSS will remain at the 0.02 Hz level until the data can be evaluated and a more appropriate setting determined.

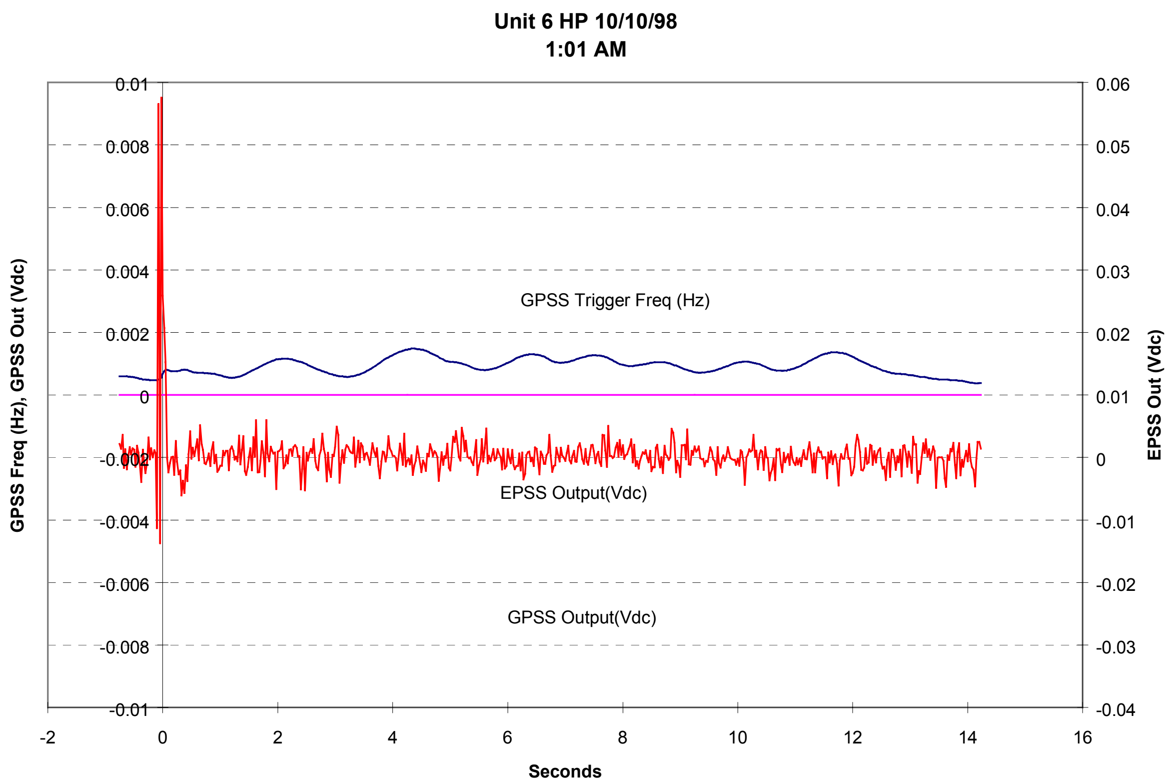
Future reports will include data for the GPSS when the HP generator is above the 0.36 pu turn on level (100 MW), or a GPSS data record trigger is captured. If none of the above events have occurred, then any captured data record will be included to show continued operation of the unit. An LP generator record will also be included to verify continued operation.

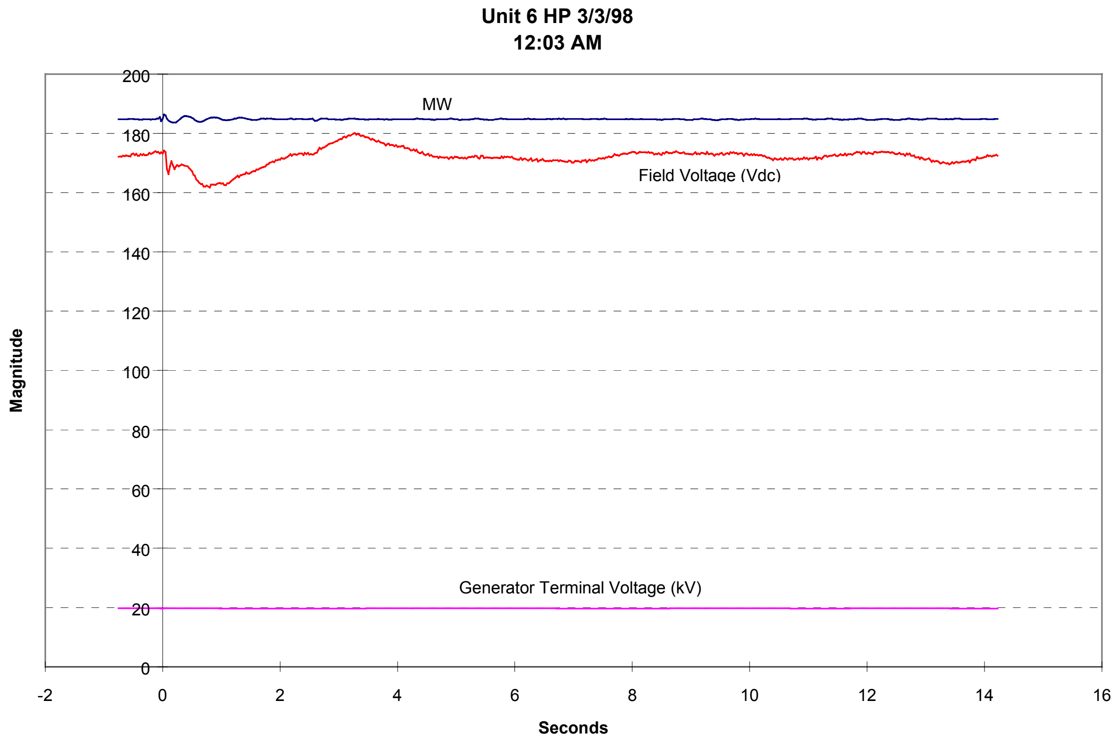
Attachments


Unit 6 HP 10/6/98
9:47 AM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
Magnitude
Seconds
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16

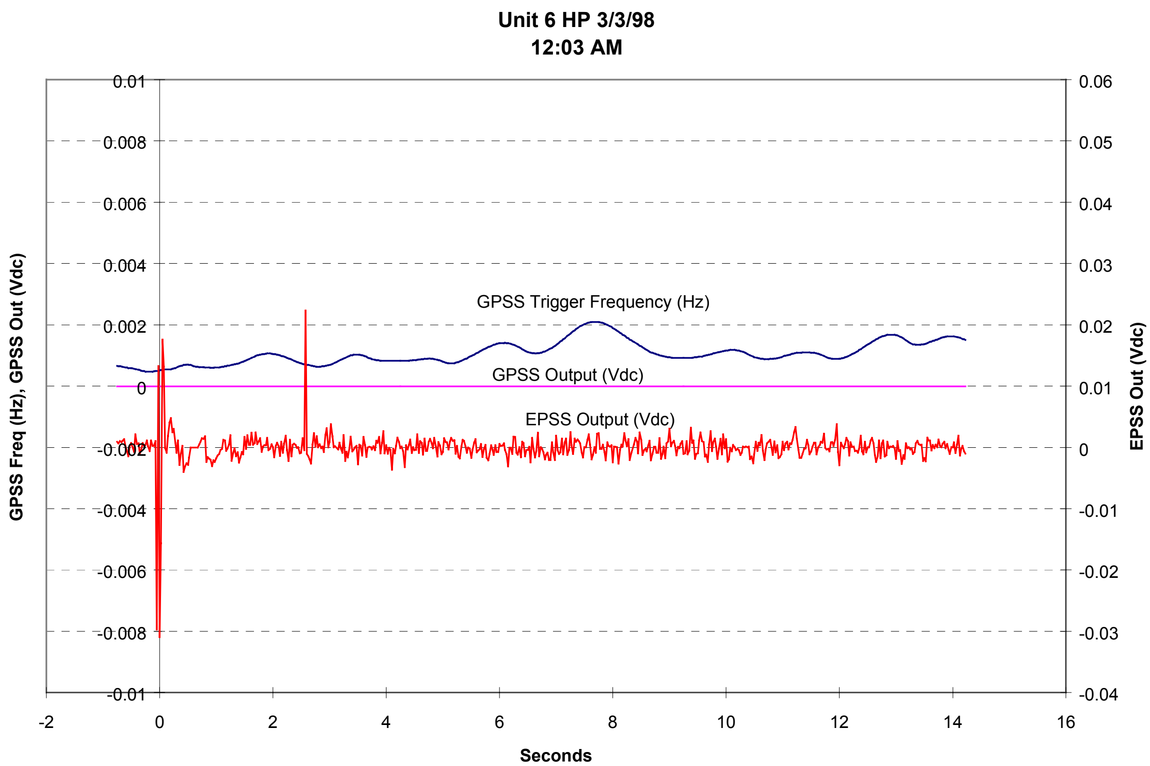

Unit 6 HP 10/6/98
9:47 AM
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16


Unit 6 HP 10/10/98
1:01 AM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
Magnitude
Seconds
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16

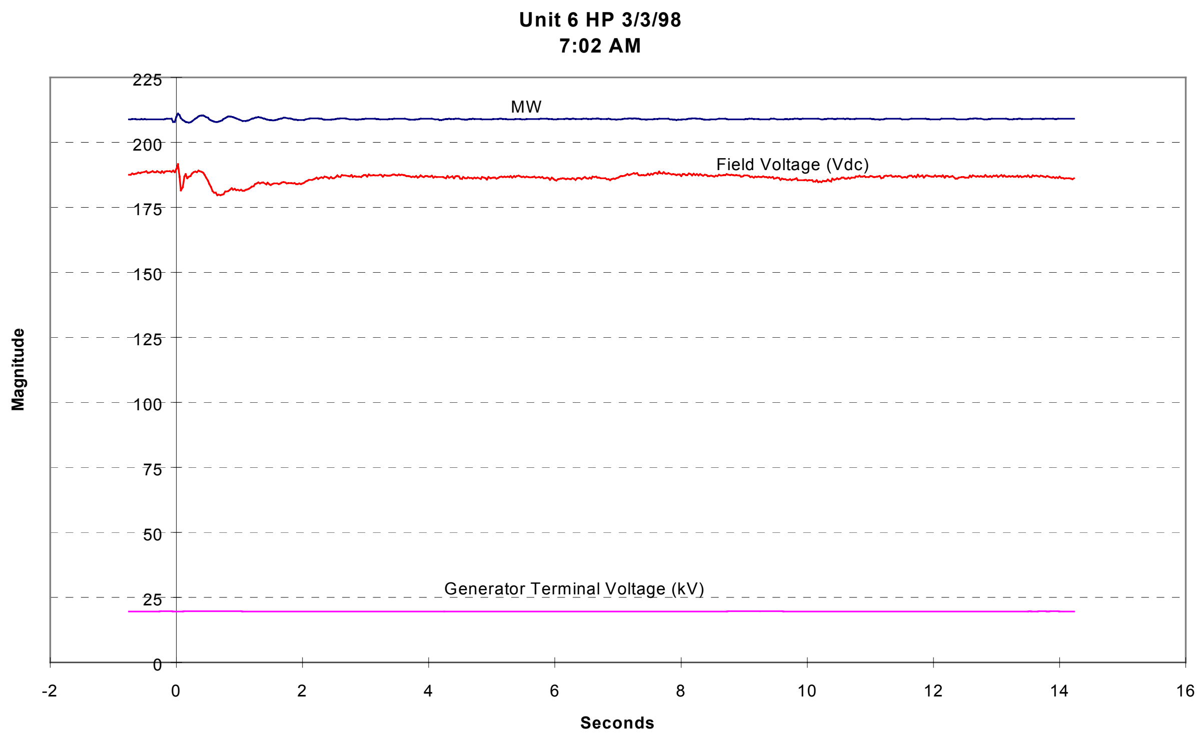

Unit 6 HP 10/10/98
1:01 AM
GPSS Trigger Freq (Hz)
EPSS Output(Vdc)
GPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

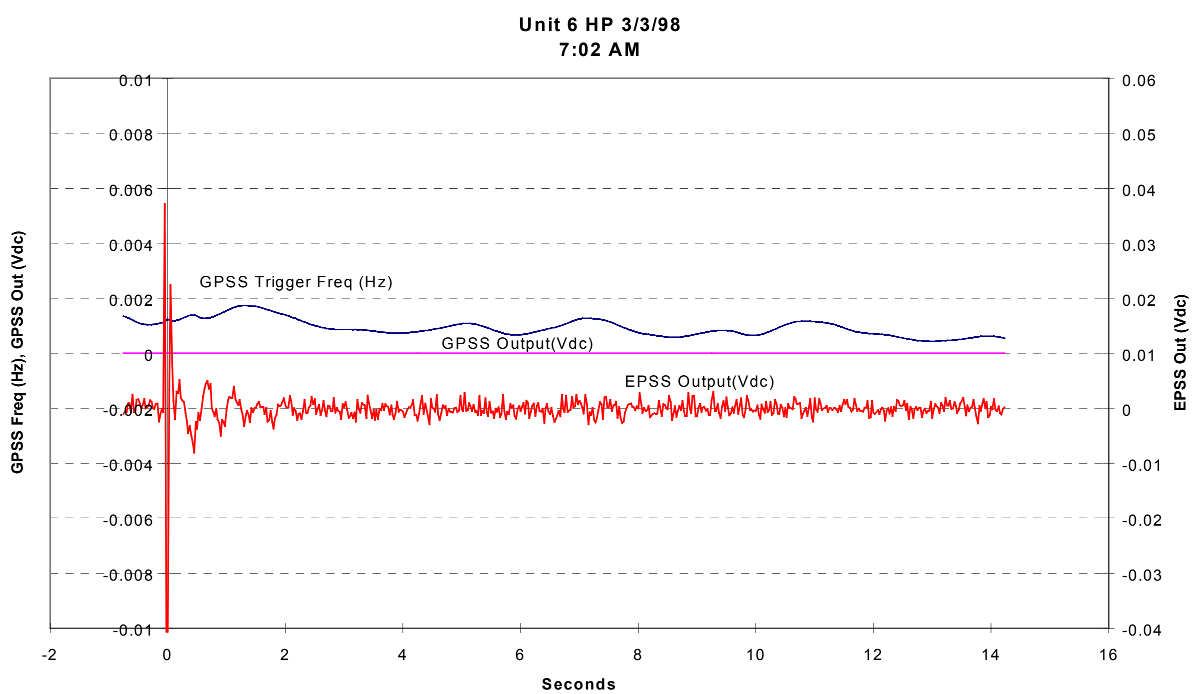


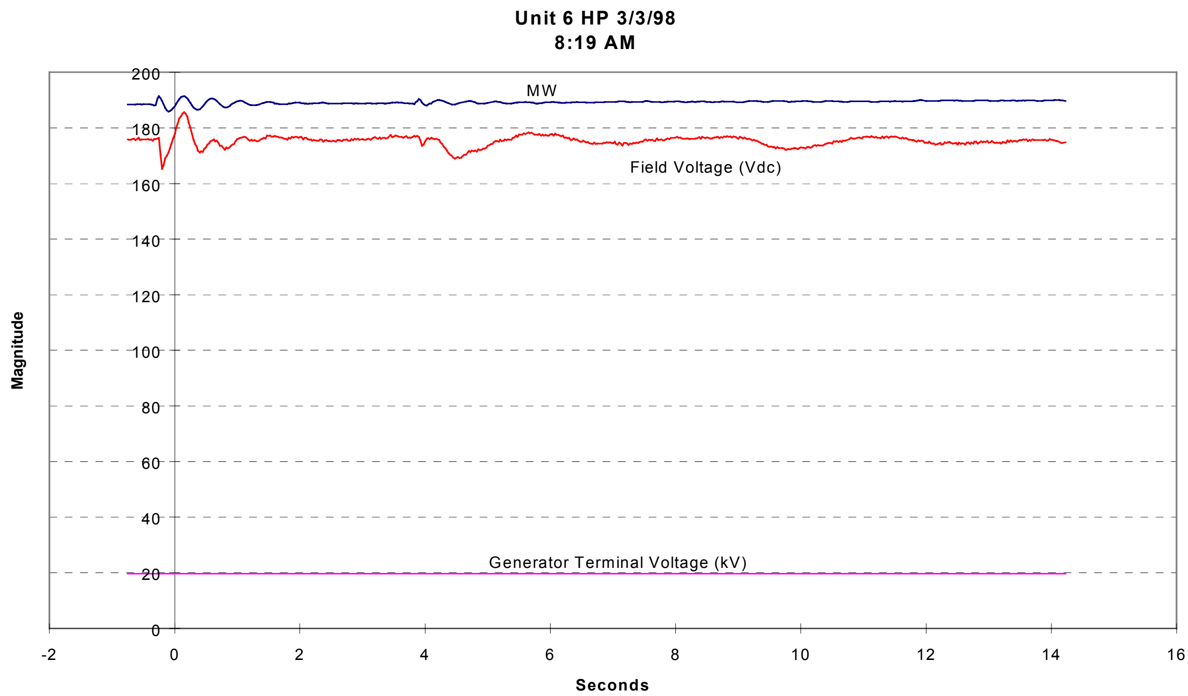
Unit 6 HP 3/3/98
12:03 AM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
200
180
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16
Seconds

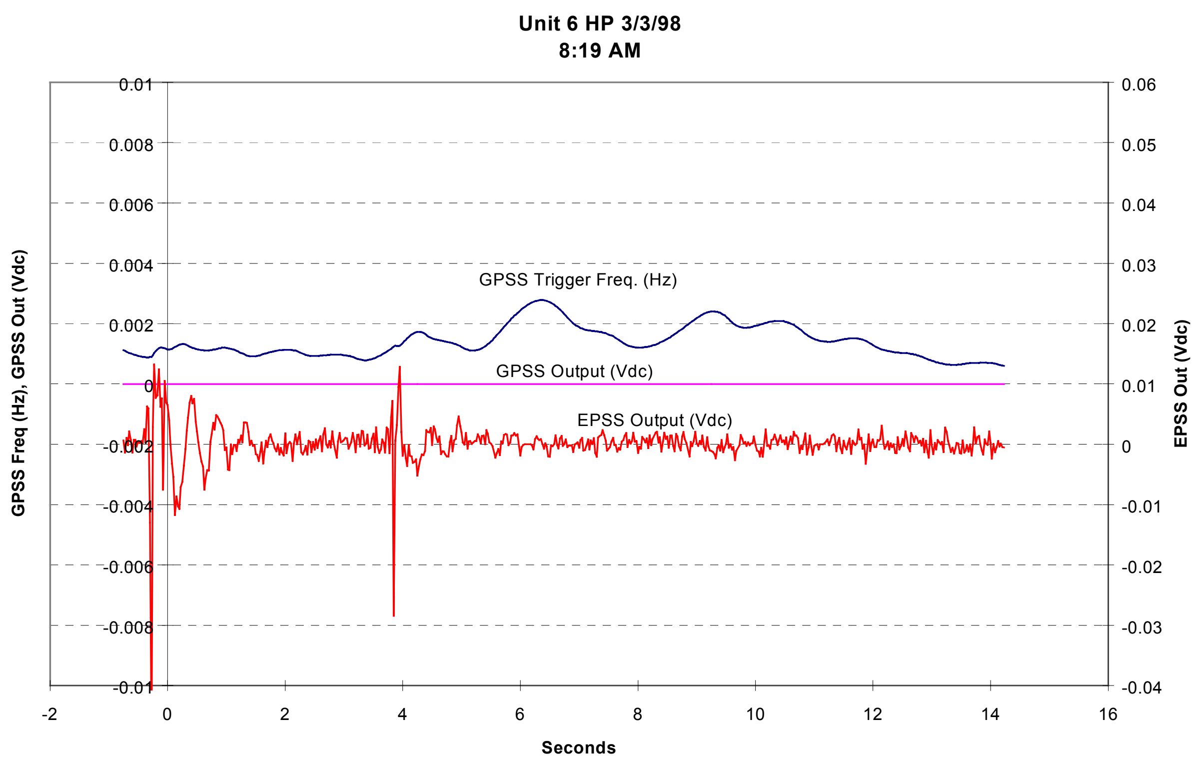


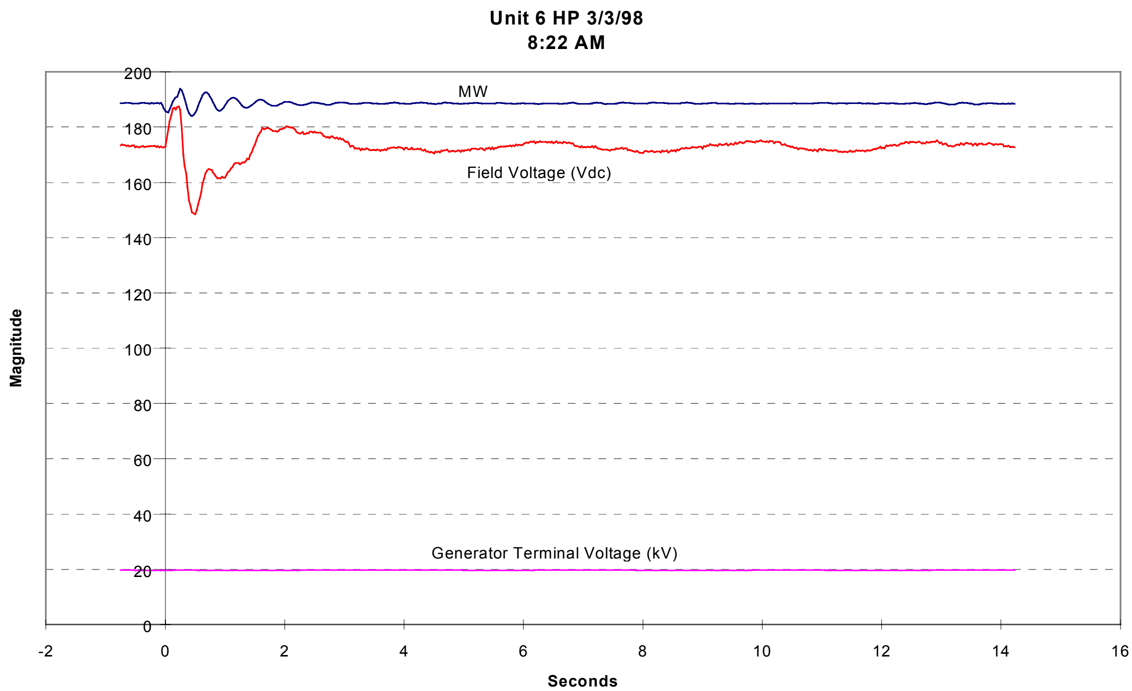
Unit 6 HP 3/3/98
12:03 AM
GPSS Trigger Frequency (Hz)
GPSS Output (Vdc)
EPSS Output (Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16
Seconds

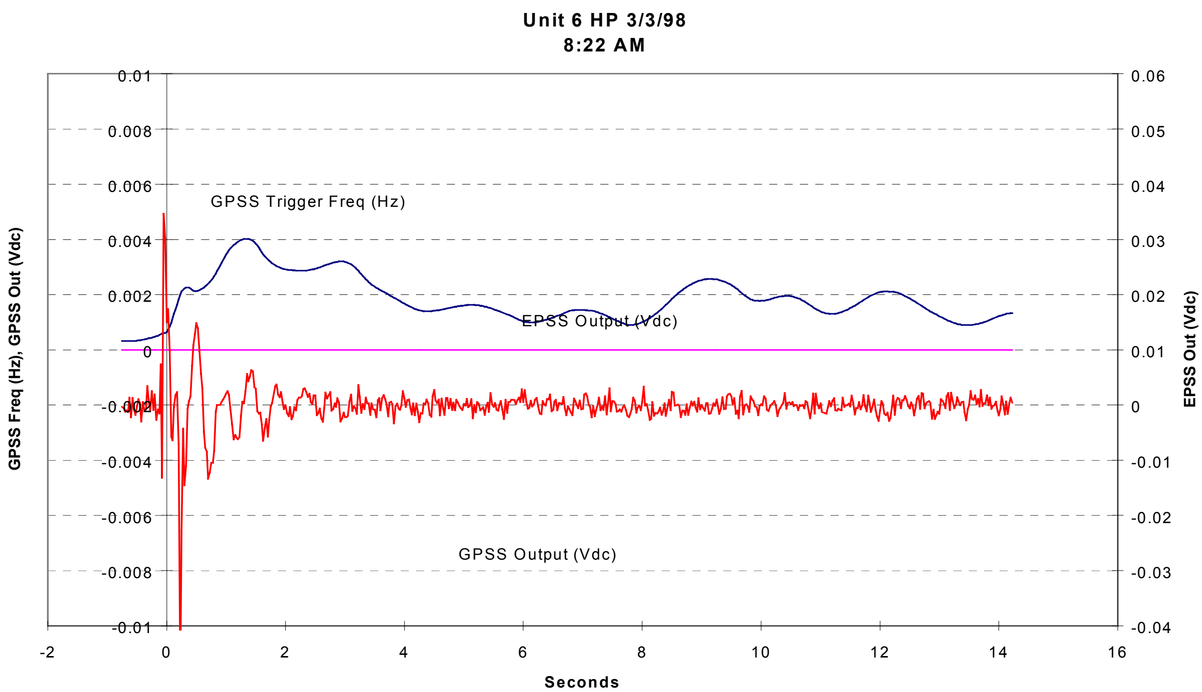

Unit 6 HP 3/3/98
7:02 AM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Seconds
225
200
175
150
125
100
75
50
25
0
-2
0
2
4
6
8
10
12
14
16

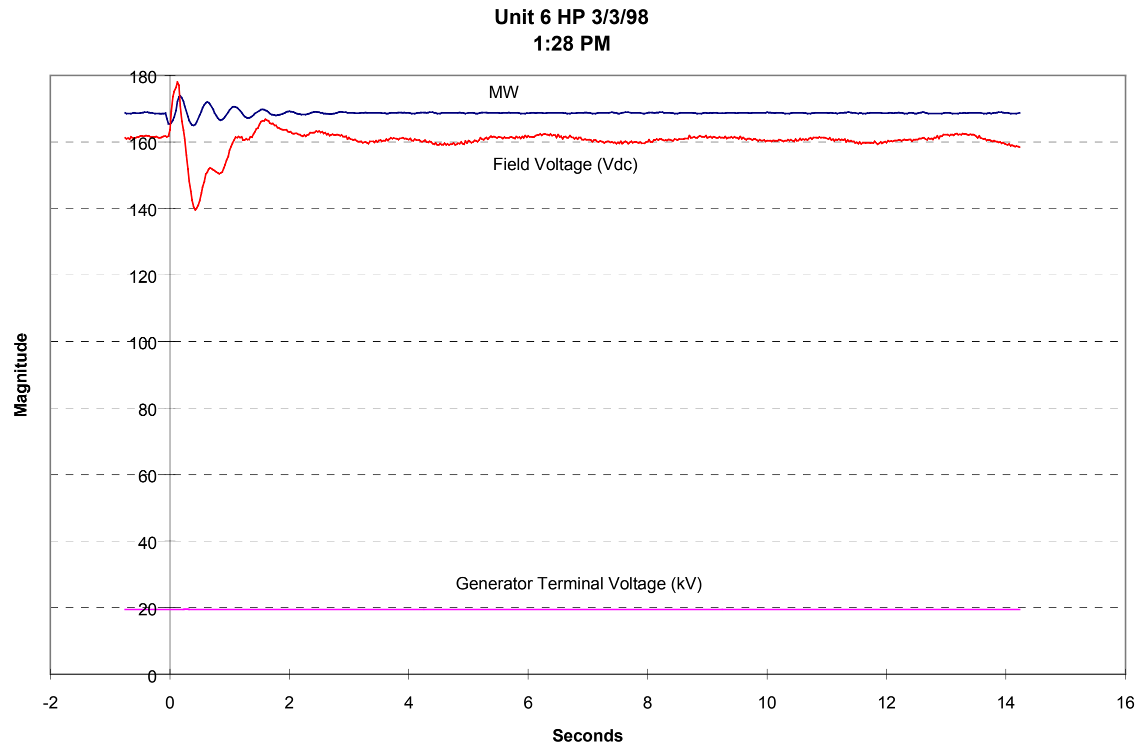

Unit 6 HP 3/3/98
7:02 AM
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

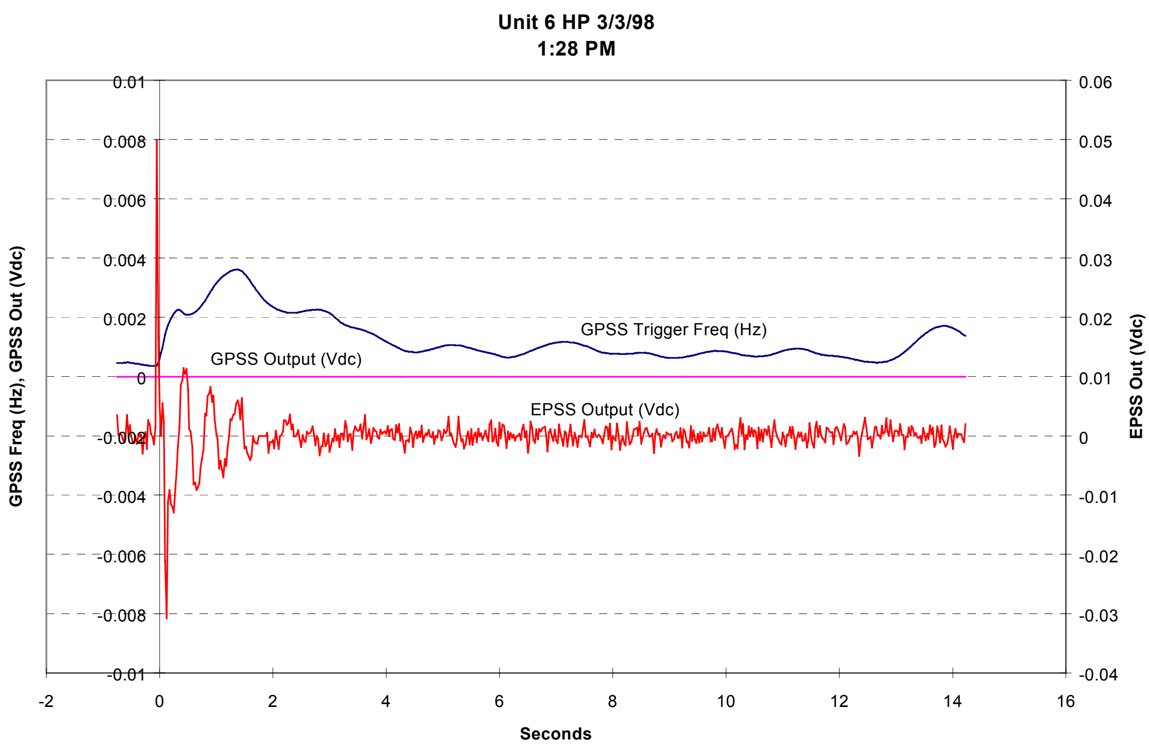

Unit 6 HP 3/3/98
8:19 AM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
200
180
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16
Seconds

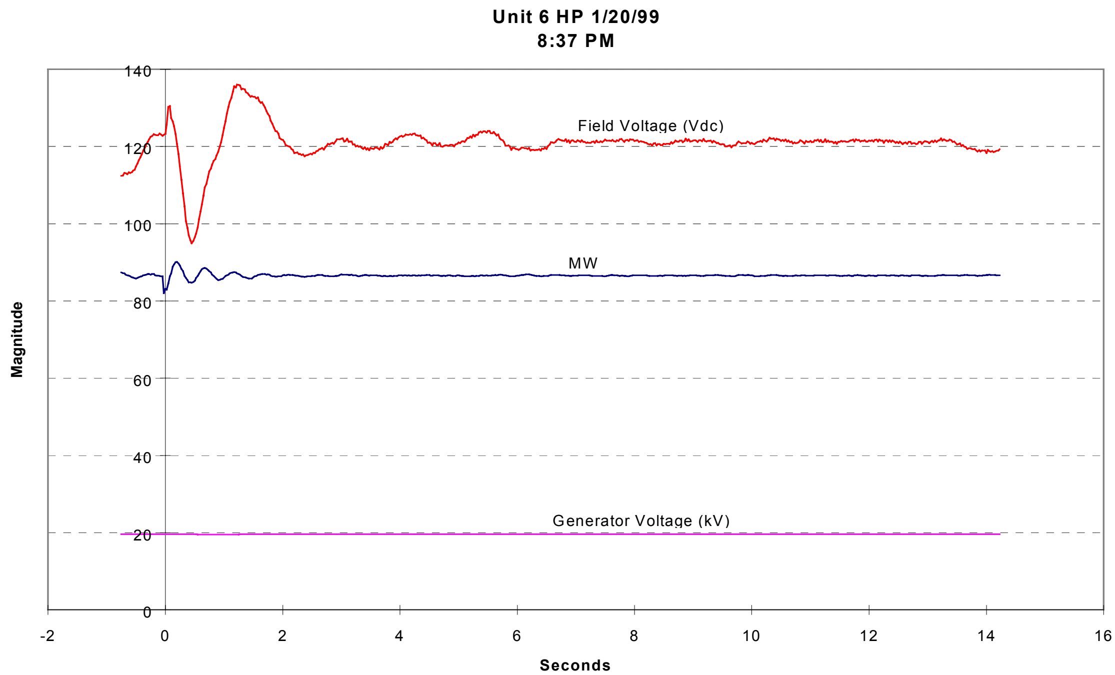

Unit 6 HP 3/3/98
8:19 AM
GPSS Trigger Freq. (Hz)
GPSS Output (Vdc)
EPSS Output (Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16
Seconds

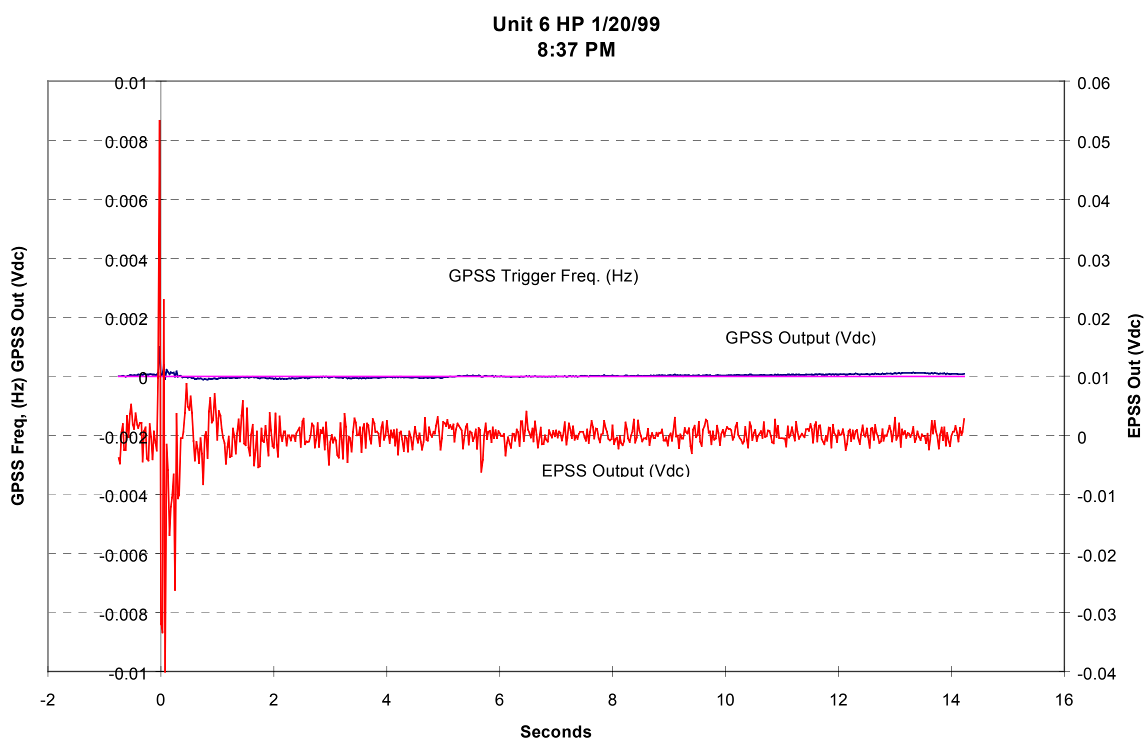

Unit 6 HP 3/3/98
8:22 AM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Seconds
200
180
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16

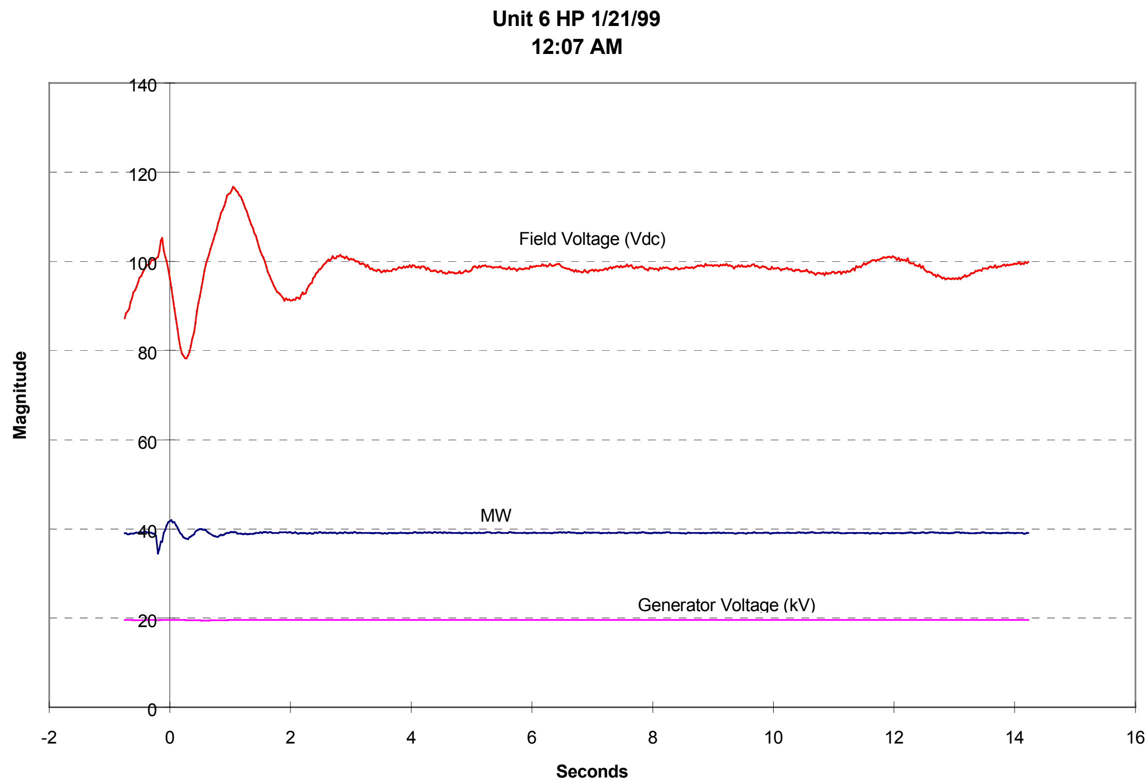

Unit 6 HP 3/3/98
8:22 AM
GPSS Trigger Freq (Hz)
EPSS Output (Vdc)
GPSS Output (Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

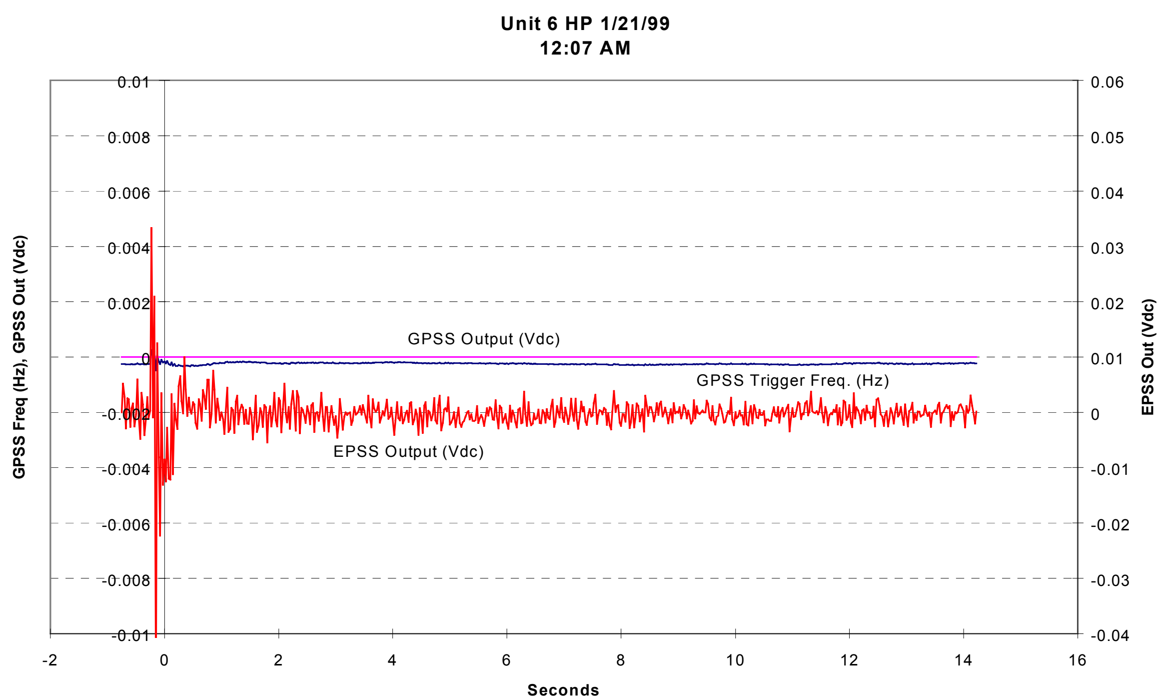

Unit 6 HP 3/3/98
1:28 PM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Seconds
180
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16

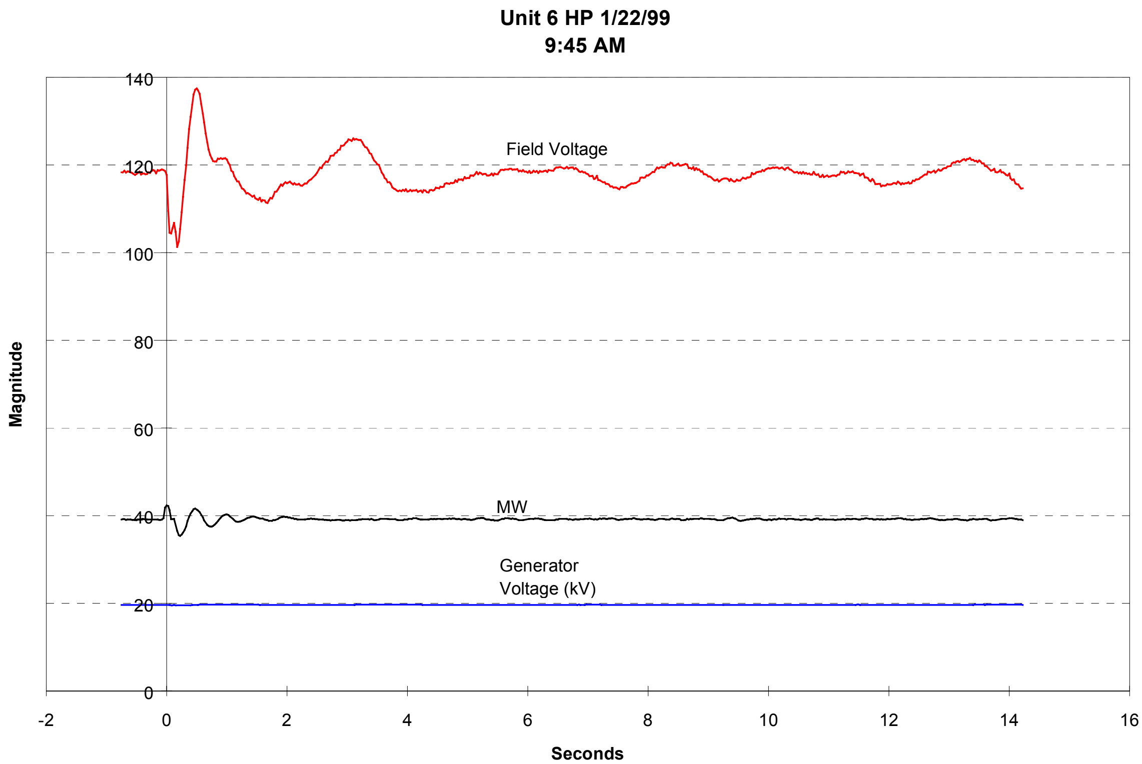

Unit 6 HP 3/3/98
1:28 PM
GPSS Trigger Freq (Hz)
GPSS Output (Vdc)
EPSS Output (Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

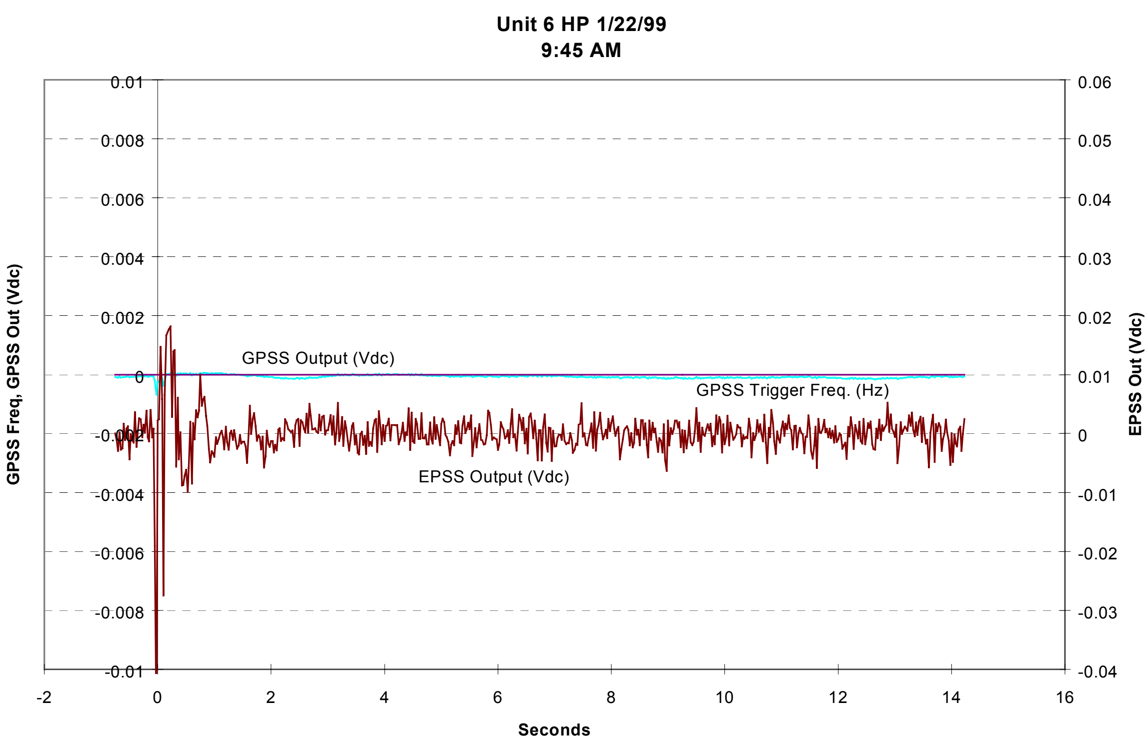

Unit 6 HP 1/20/99
8:37 PM
Field Voltage (Vdc)
MW
Generator Voltage (kV)
Magnitude
Seconds
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16

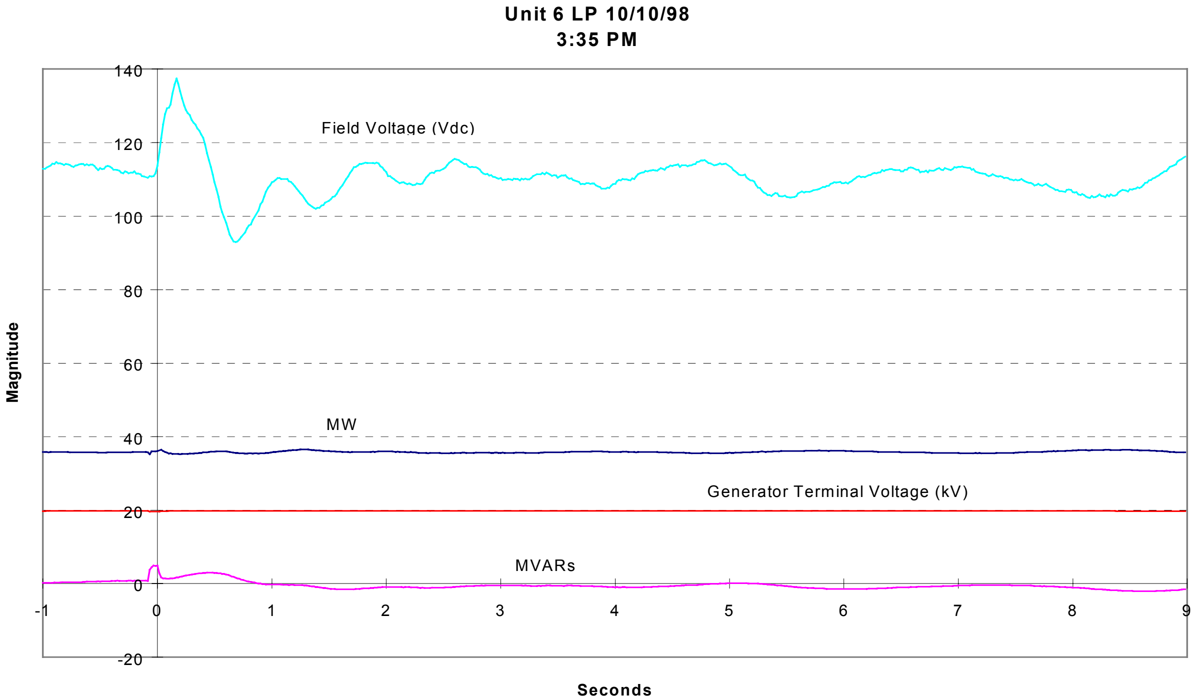

Unit 6 HP 1/20/99
8:37 PM
GPSS Trigger Freq. (Hz)
GPSS Output (Vdc)
EPSS Output (Vdc)
GPSS Freq, (Hz) GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16


Unit 6 HP 1/21/99
12:07 AM
Magnitude
Seconds
Field Voltage (Vdc)
MW
Generator Voltage (kV)
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16

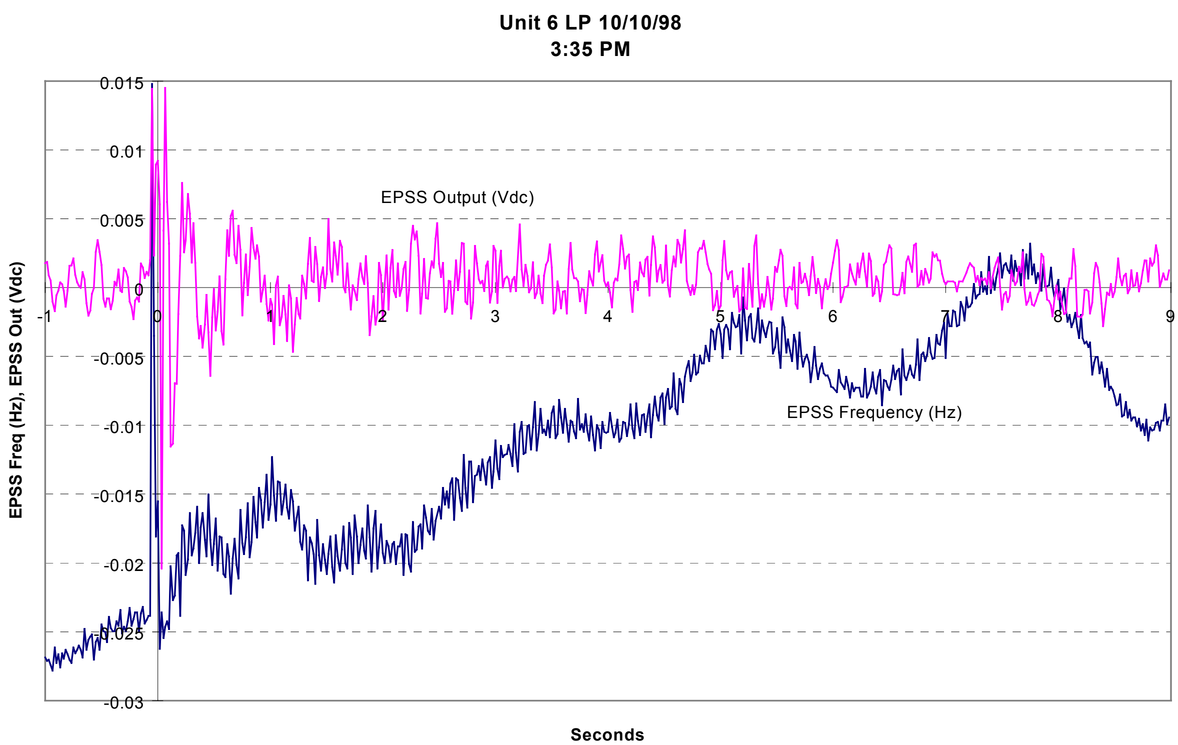

Unit 6 HP 1/21/99
12:07 AM
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
GPSS Output (Vdc)
GPSS Trigger Freq. (Hz)
EPSS Output (Vdc)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16


Unit 6 HP 1/22/99
9:45 AM
Magnitude
Seconds
Field Voltage
MW
Generator
Voltage (kV)
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16

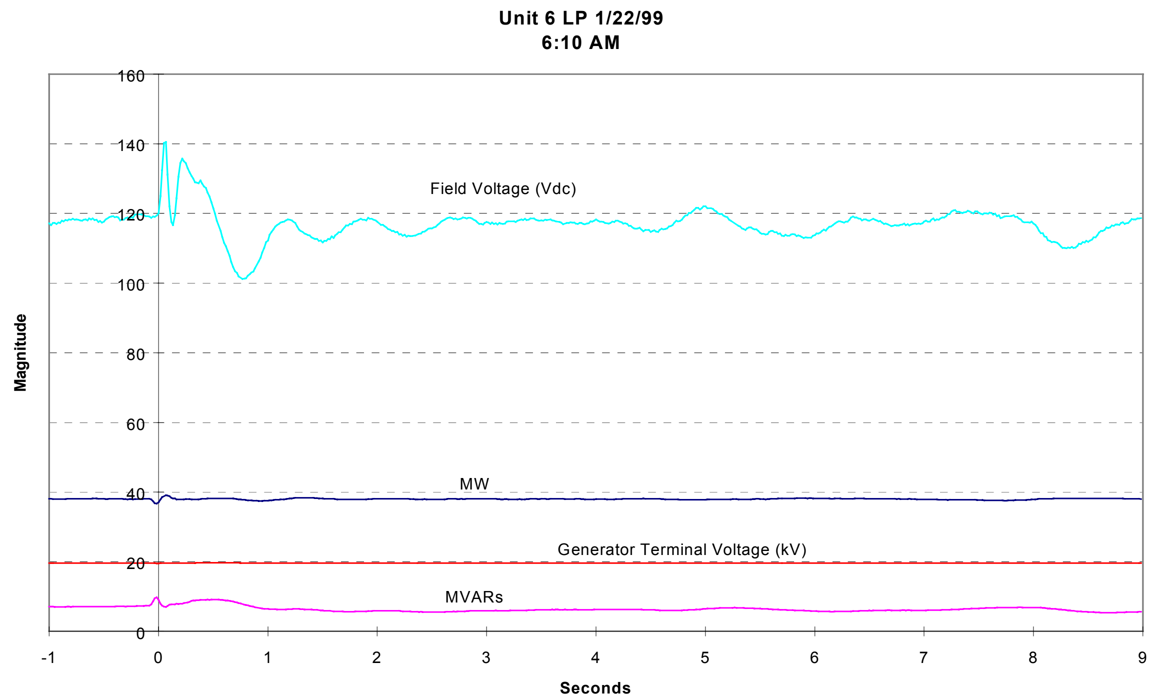

Unit 6 HP 1/22/99
9:45 AM
GPSS Freq, GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
GPSS Output (Vdc)
GPSS Trigger Freq. (Hz)
EPSS Output (Vdc)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16



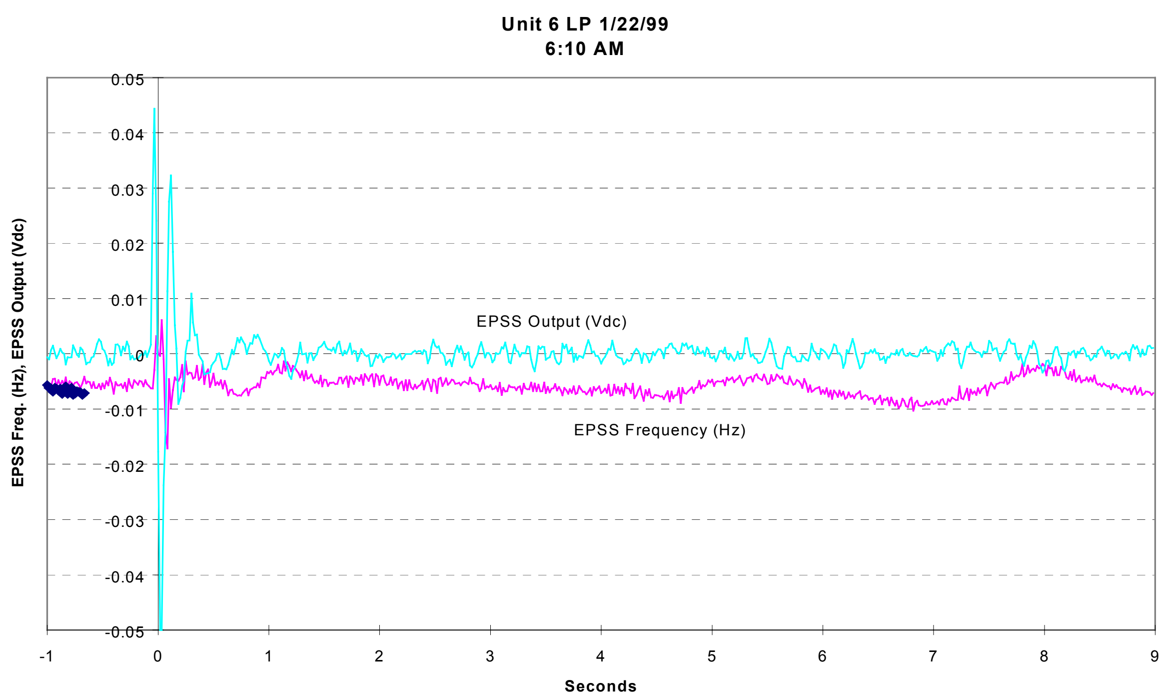
Unit 6 LP 10/10/98
3:35 PM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
MVARs
Magnitude
Seconds
140
120
100
80
60
40
20
0
-20
-1
0
1
2
3
4
5
6
7
8
9



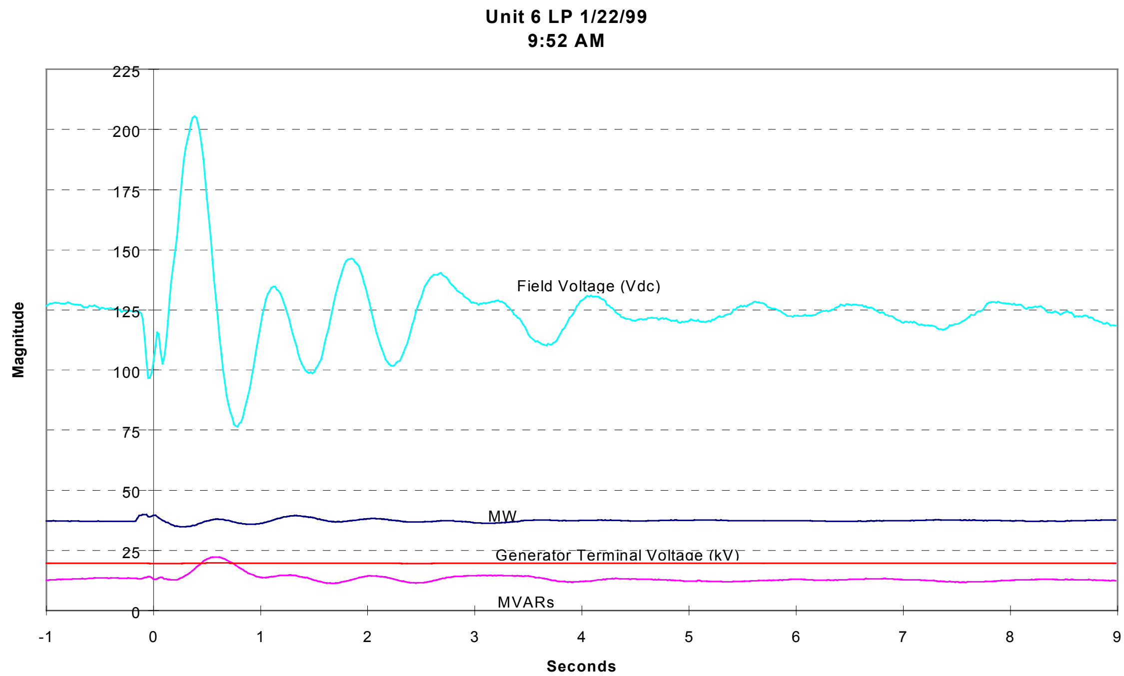
Unit 6 LP 10/10/98
3:35 PM
EPSS Output (Vdc)
EPSS Frequency (Hz)
EPSS Freq (Hz), EPSS Out (Vdc)
Seconds
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
-1
0
1
2
3
4
5
6
7
8
9

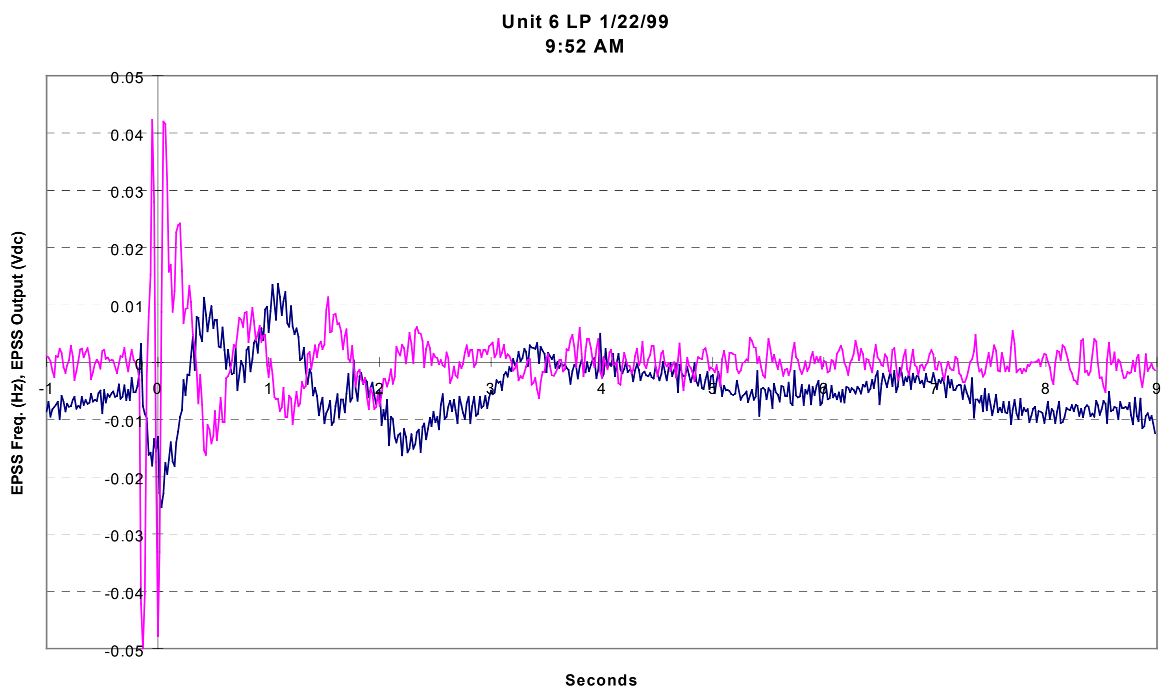


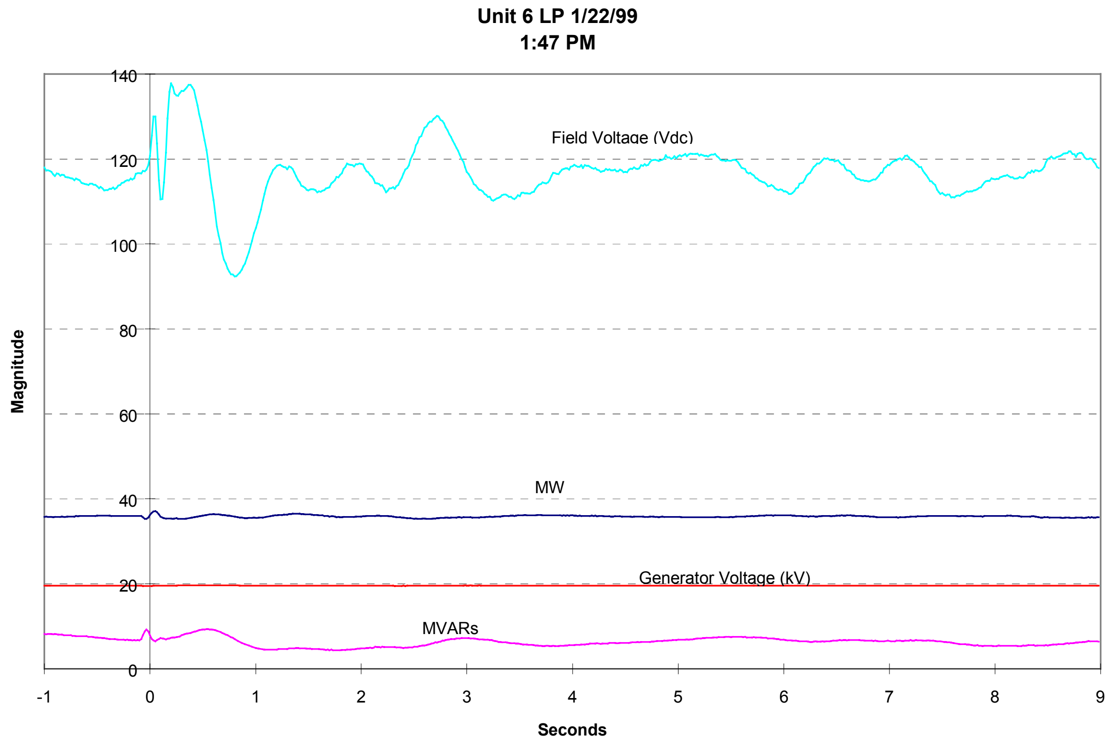
Unit 6 LP 1/22/99
6:10 AM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
MVARs
Magnitude
Seconds
160
140
120
100
80
60
40
20
0
-1
0
1
2
3
4
5
6
7
8
9

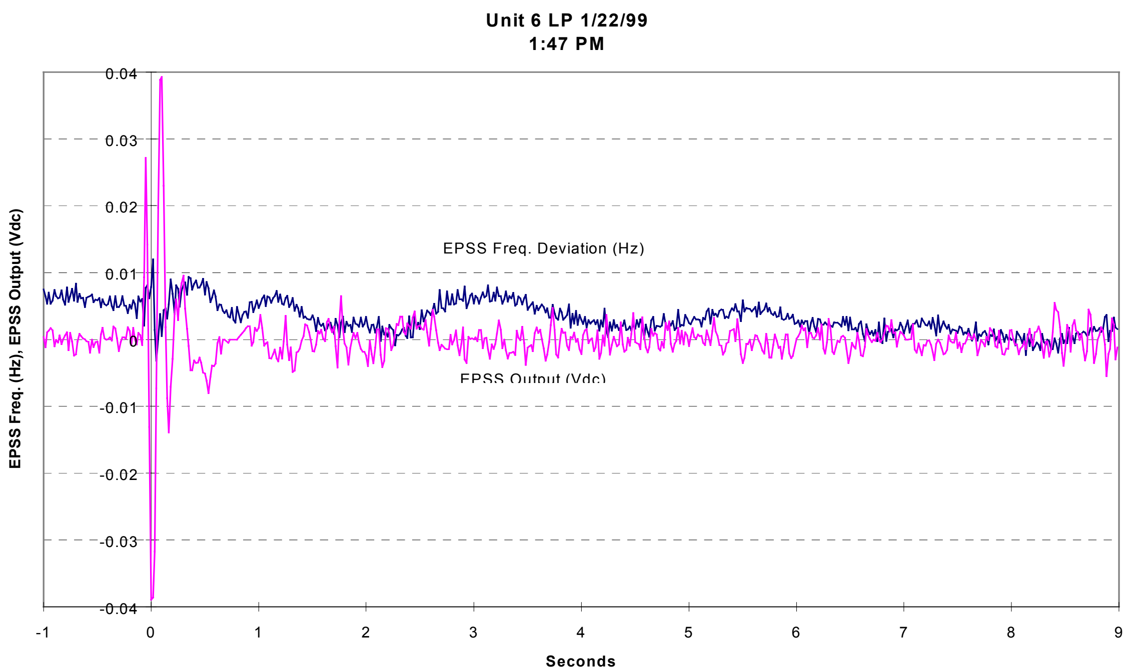


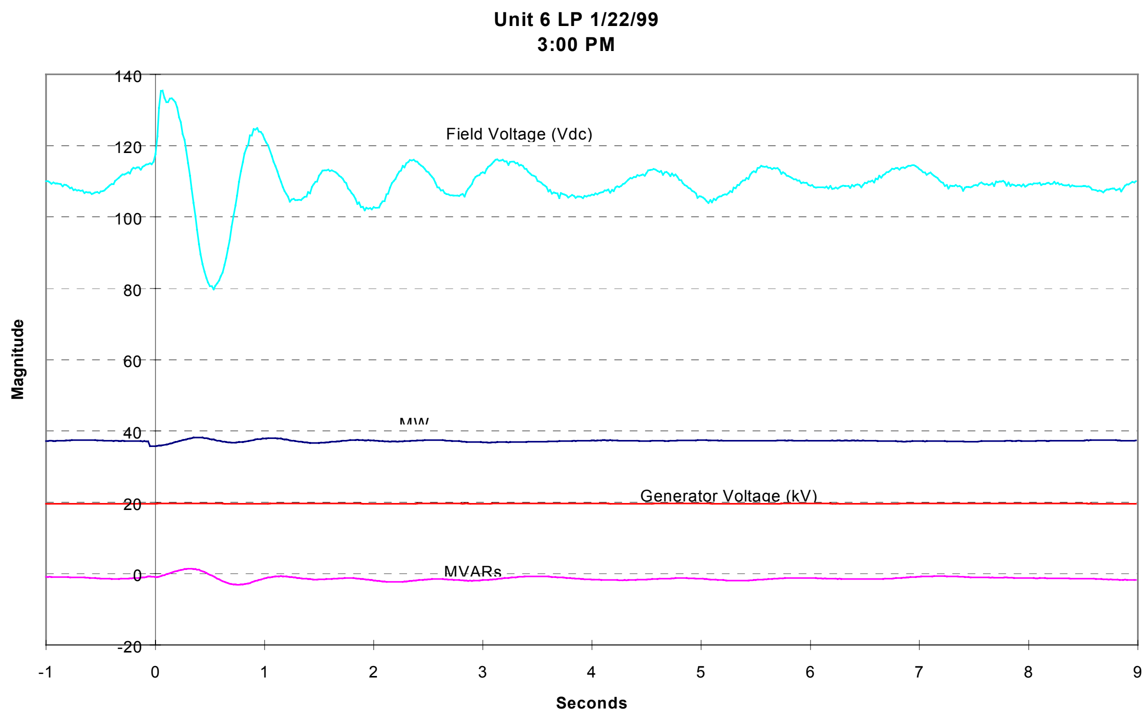
Unit 6 LP 1/22/99
6:10 AM
EPSS Output (Vdc)
EPSS Frequency (Hz)
EPSS Freq. (Hz), EPSS Output (Vdc)
Seconds
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-1
0
1
2
3
4
5
6
7
8
9

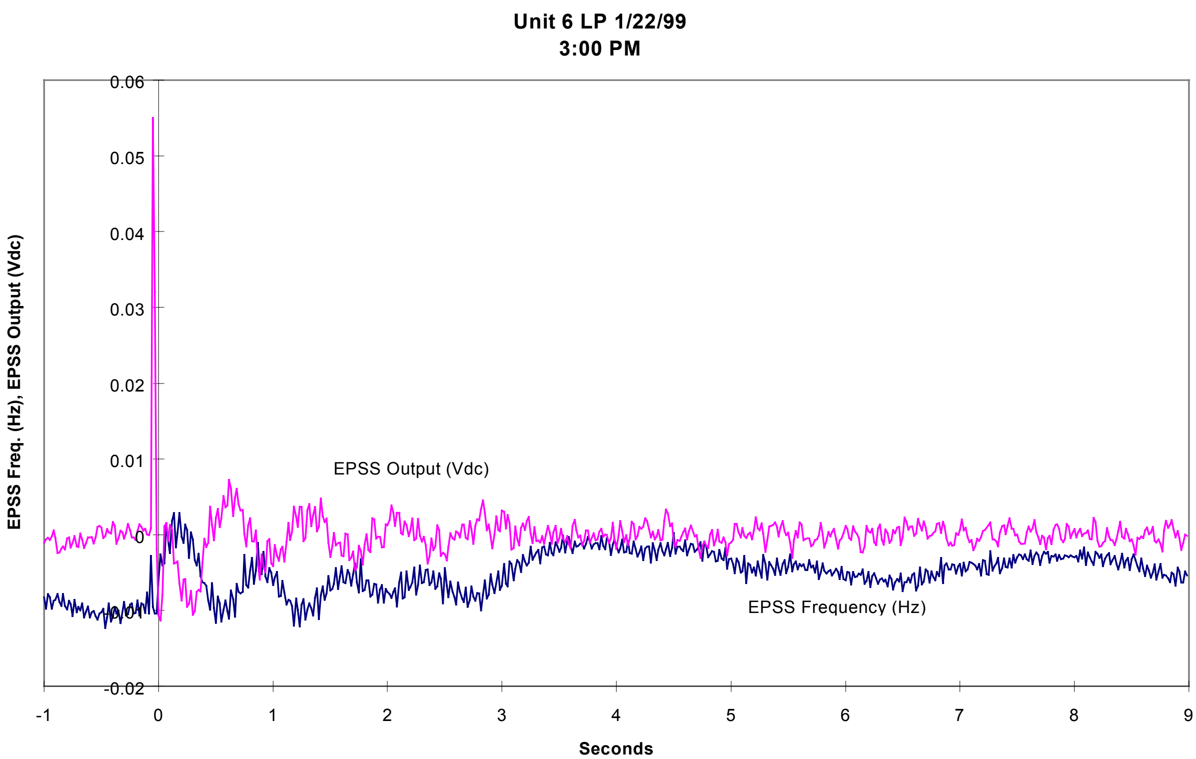

Unit 6 LP 1/22/99
9:52 AM
Magnitude
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
MVARs
Seconds


Unit 6 LP 1/22/99
9:52 AM
EPSS Freq. (Hz), EPSS Output (Vdc)
Seconds


Unit 6 LP 1/22/99
1:47 PM
Field Voltage (Vdc)
MW
Generator Voltage (kV)
MVARs
Magnitude
Seconds
140
120
100
80
60
40
20
0
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 1/22/99
1:47 PM
EPSS Freq. Deviation (Hz)
EPSS Output (Vdc)
EPSS Freq. (Hz), EPSS Output (Vdc)
Seconds
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 1/22/99
3:00 PM
Field Voltage (Vdc)
MW
Generator Voltage (kV)
MVARs
Magnitude
Seconds
140
120
100
80
60
40
20
0
-20
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 1/22/99
3:00 PM
EPSS Output (Vdc)
EPSS Frequency (Hz)
EPSS Freq. (Hz), EPSS Output (Vdc)
Seconds
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-1
0
1
2
3
4
5
6
7
8
9

Appendix VII
Data Collected for Unit 6 After 1/23/99

Unit: 6
Date of Work: 1/23/99 – 2/26/99

Brief Description of Work Performed

ESI engineering personnel downloaded data on 2/26/99 to collect the data records for the previous month's operation. Charts of selected data are included in the attachments to this report. The electrical power system stabilizer (EPSS) portion of the IPSS for both the HP and LP generators have triggered numerous data records. The governor power system stabilizer (GPSS) portion of the IPSS on the HP generator has not yet triggered and operated.
The charts include the MW load, the generator terminal voltage, the field voltage, GPSS trigger signal, GPSS output, EPSS sensing frequency, and EPSS output where applicable.

HP GPSS and EPSS Settings

The operating parameters for the GPSS and EPSS as well as the data recorder settings for the HP generator are tabulated below. Those marked with an asterisk have been changed since the last report.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~42 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS power-on threshold (p.u. MVA)	0.36	~100 MW
GPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS turn-on frequency (Hz)	0.02	
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	5	0.75 seconds
Number half cycles between logger saves	3	15 second record
Autotrigger Values		
p.u. GPSS Trigger setpoint (Hz)	0.02 *	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	20 *	0.166 seconds
Priority	3	
EPSS Output	0.02	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	20 *	0.166 seconds
Priority	2	

LP EPSS Settings

The operating parameters for the EPSS as well as the data recorder settings for the LP generator are tabulated below. Those marked with an asterisk have been changed since the last report.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~33 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~11 MW
GPSS power-on threshold (p.u. MVA)	1.0	No GPSS
GPSS power-on MVA hysteresis (p.u. MVA)	0	
GPSS turn-on frequency (Hz)	0.5	
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	10	1.0 seconds
Number half cycles between logger saves	2	10 second record
Autotrigger Values		

On/Off Control	Setting	Comment
EPSS Output	0.02*	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	20	0.166 seconds
Priority	2	

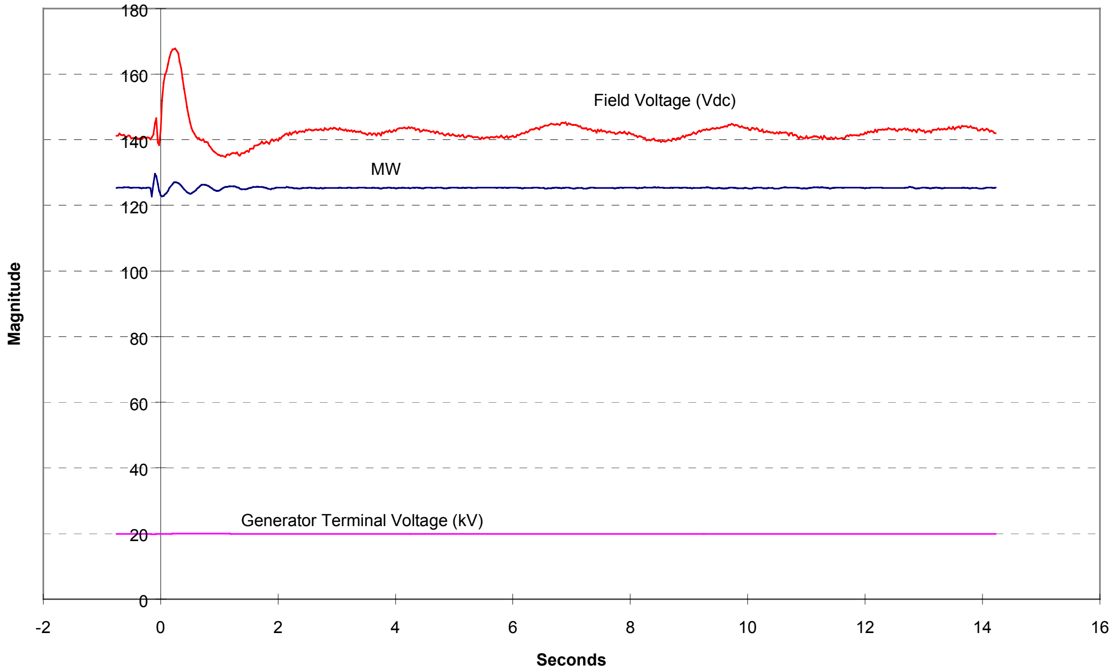
Observations

The MW load recorded during the events captured in February 1999 are all above the ON enable setpoint of 0.36 p.u. or 100 MW for any GPSS operation. However, the data records indicate the GPSS trigger frequency never approached the 0.02 Hz turn on threshold.

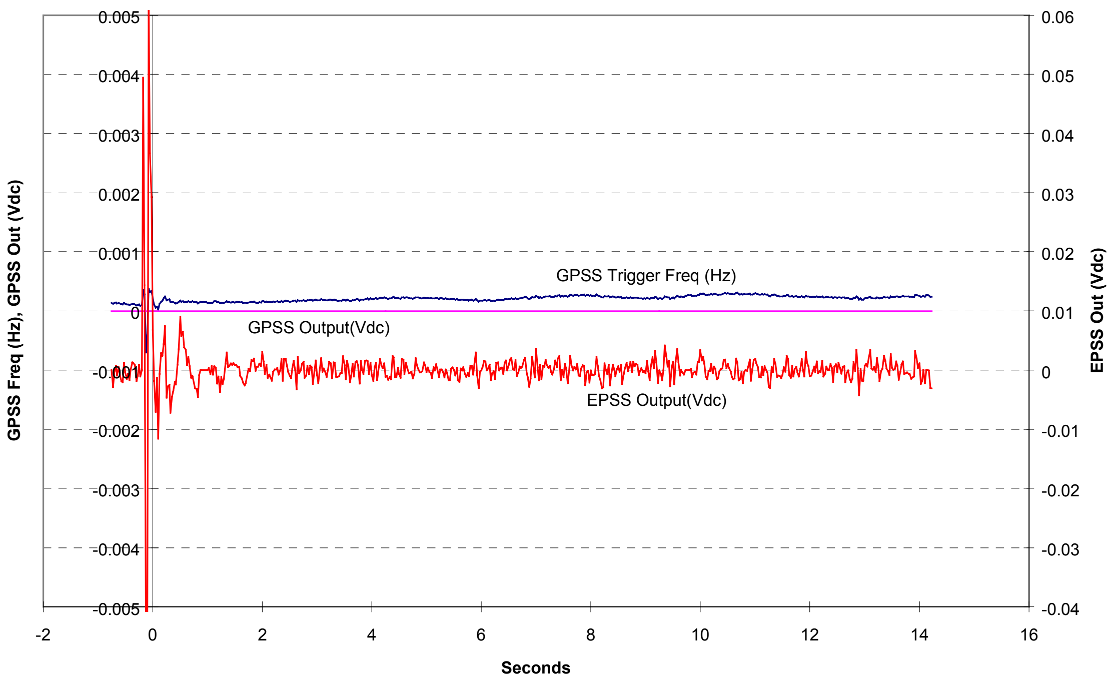
The data recorder trigger threshold for the GPSS will be reset to a lower value in incremental steps until a data record is obtained for a GPSS trigger indication. The actual GPSS trigger setpoint will remained unchanged and will operate only if the frequency excursion exceeds the 0.02 Hz threshold. The data will be evaluated prior to making any actual operational changes.

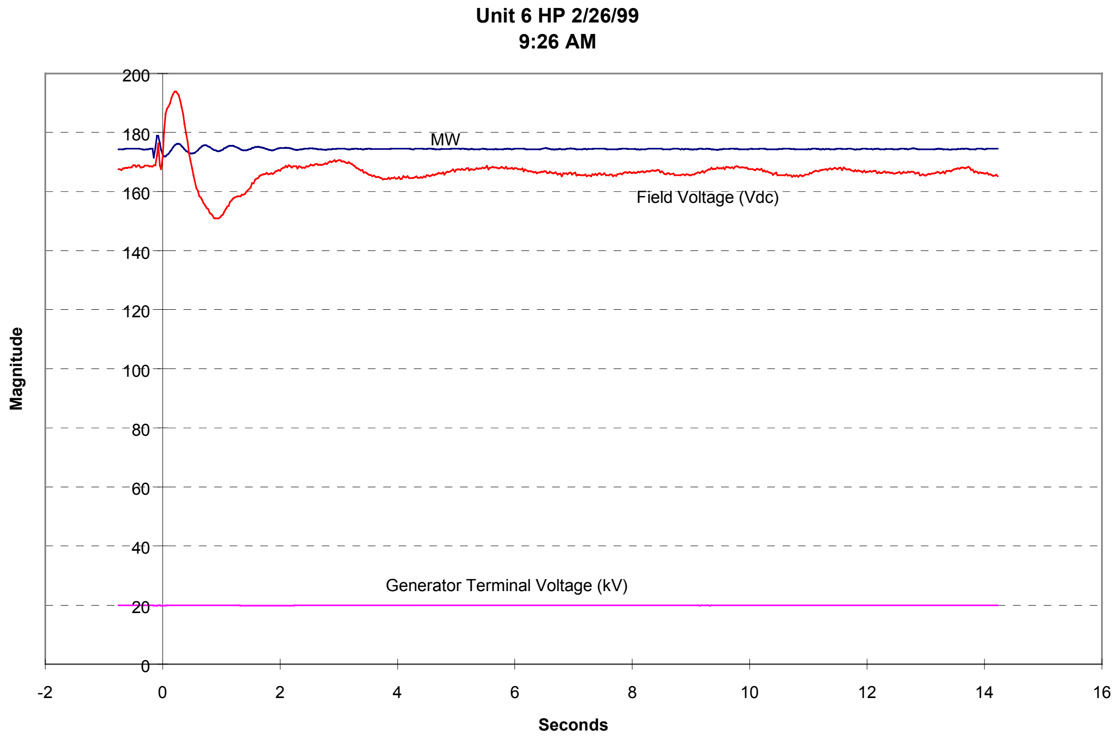
Attachments

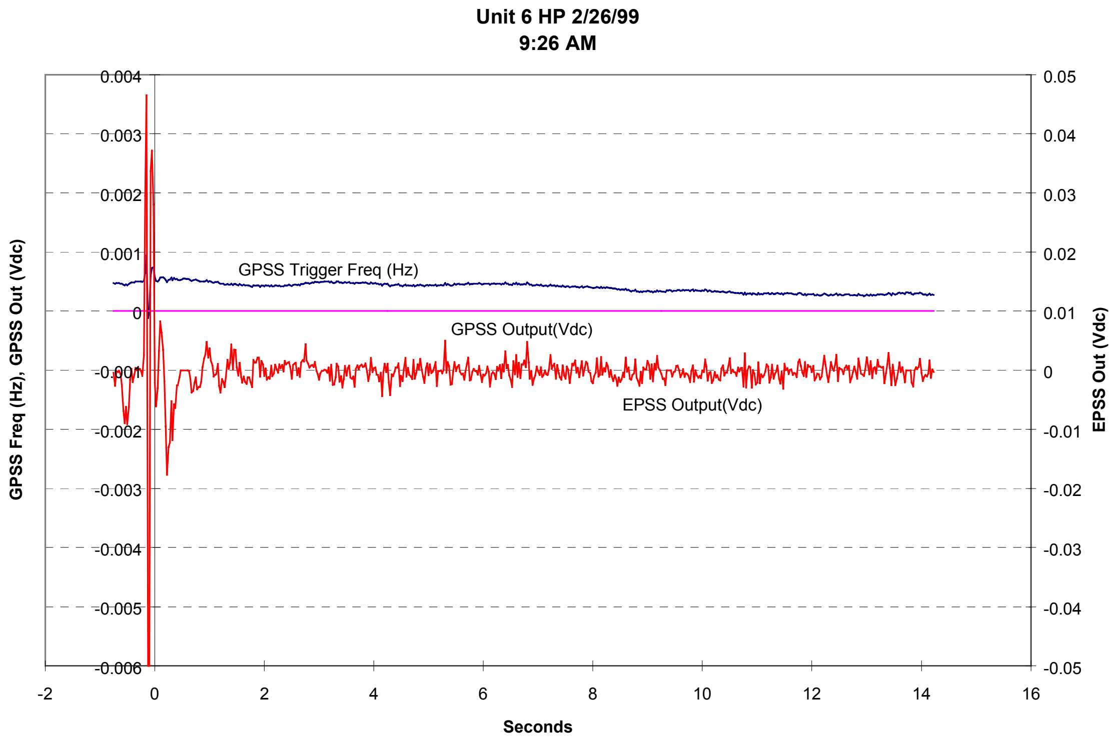
Unit 6 HP 2/26/99
8:59 AM



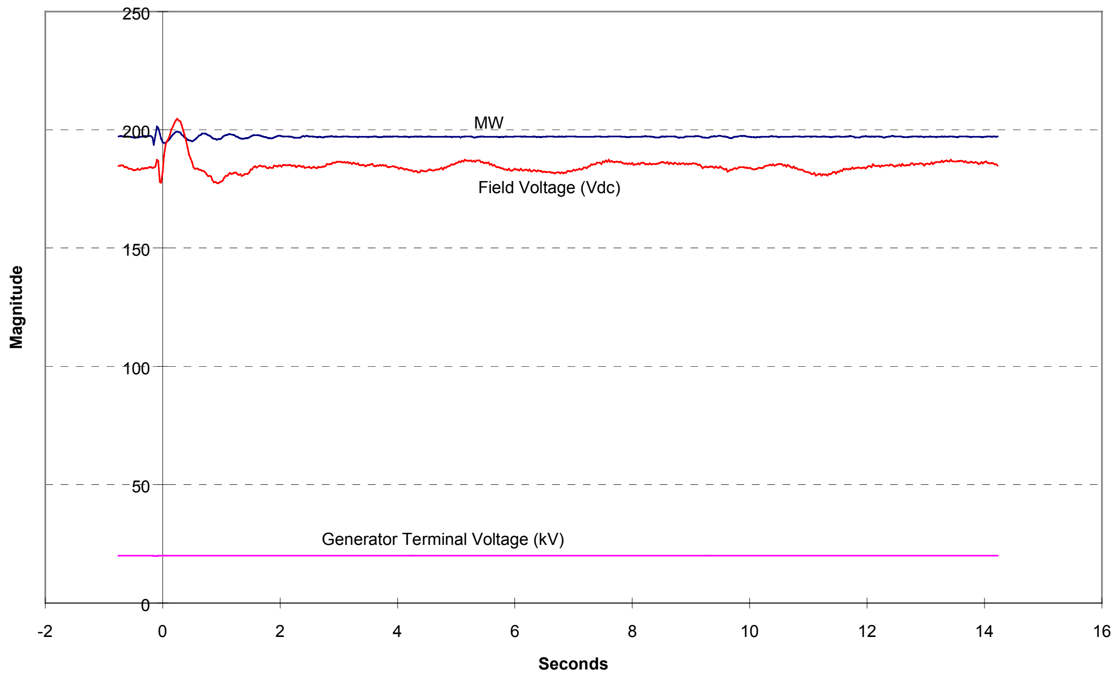
Unit 6 HP 2/26/99
8:59 AM



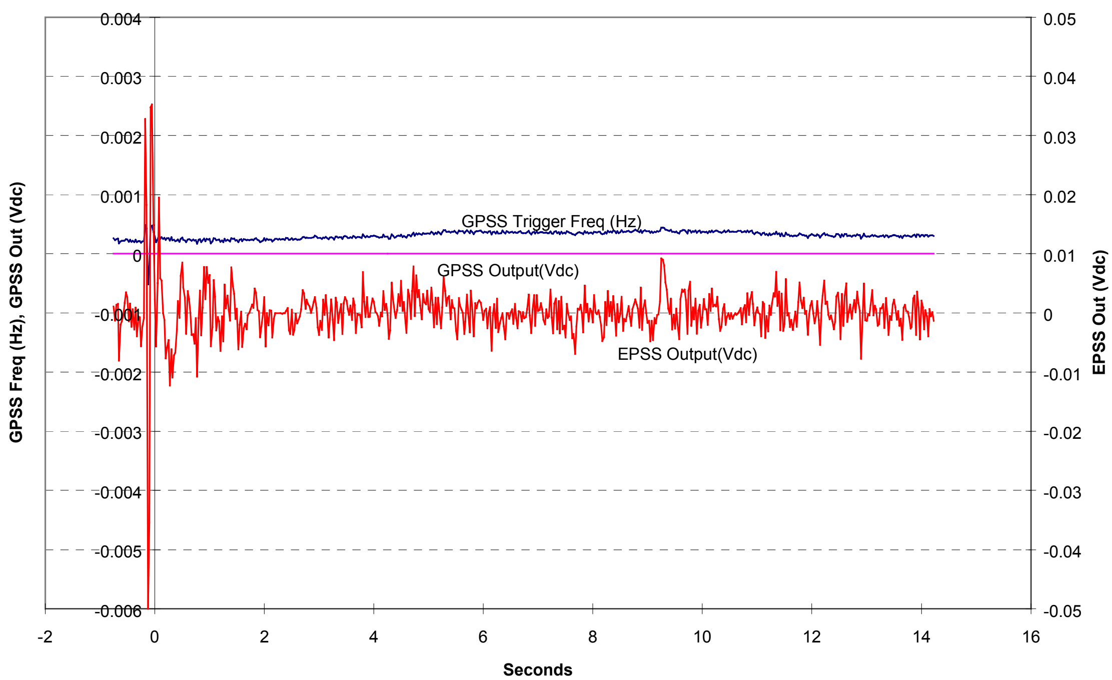

Unit 6 HP 2/26/99
9:26 AM
Magnitude
Seconds
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
200
180
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16

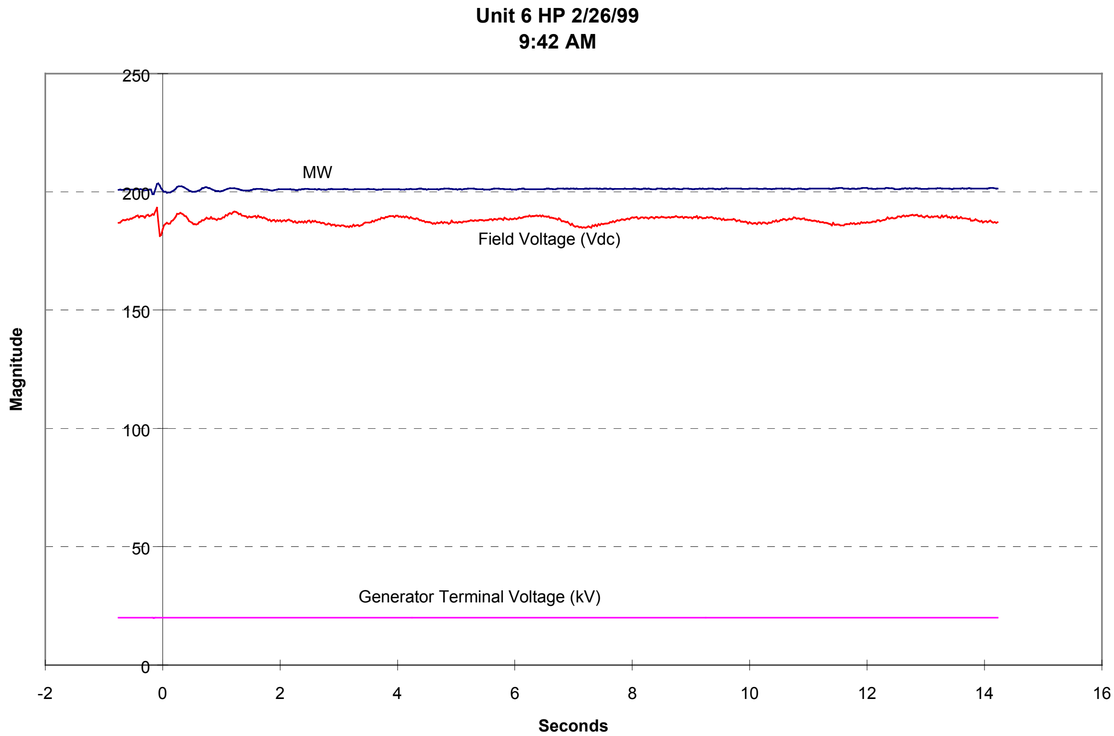

Unit 6 HP 2/26/99
9:26 AM
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-2
0
2
4
6
8
10
12
14
16

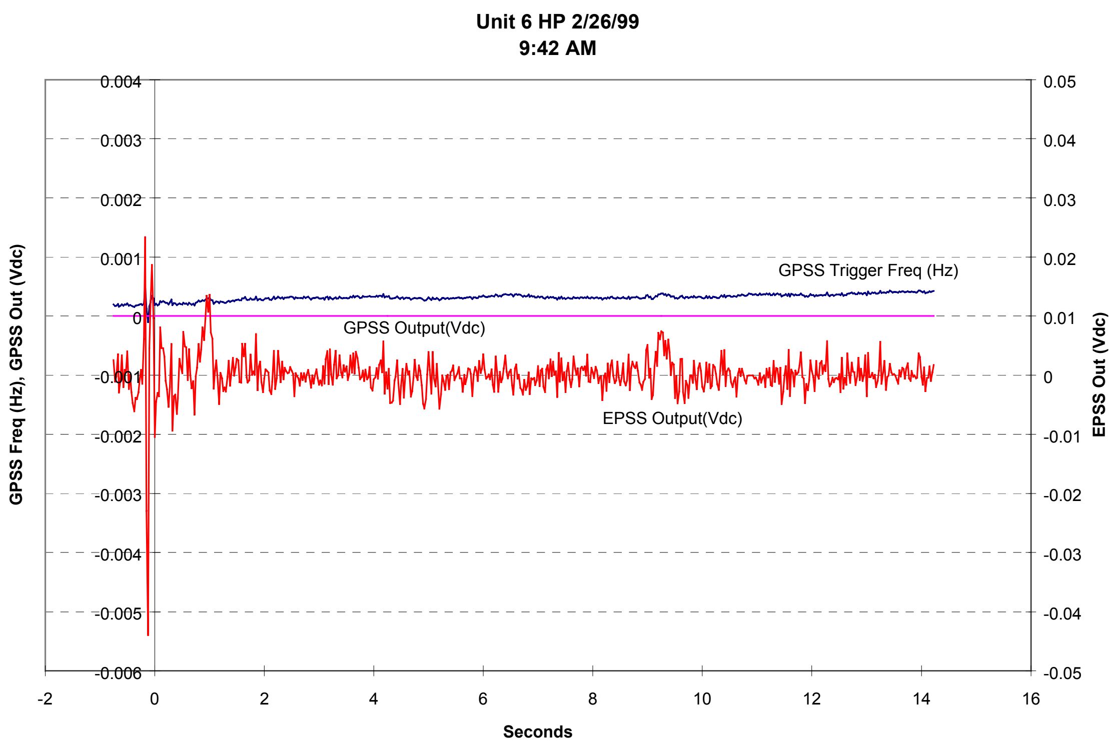
Unit 6 HP 2/26/99
9:38 AM

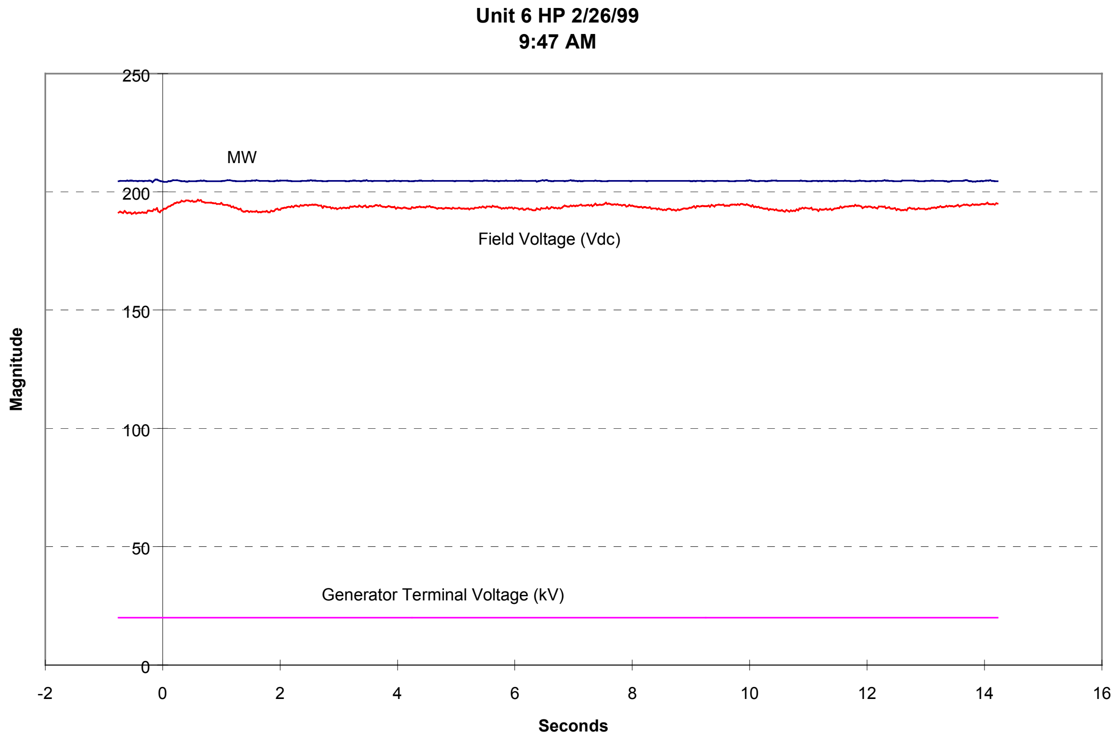


Unit 6 HP 2/26/99
9:38 AM

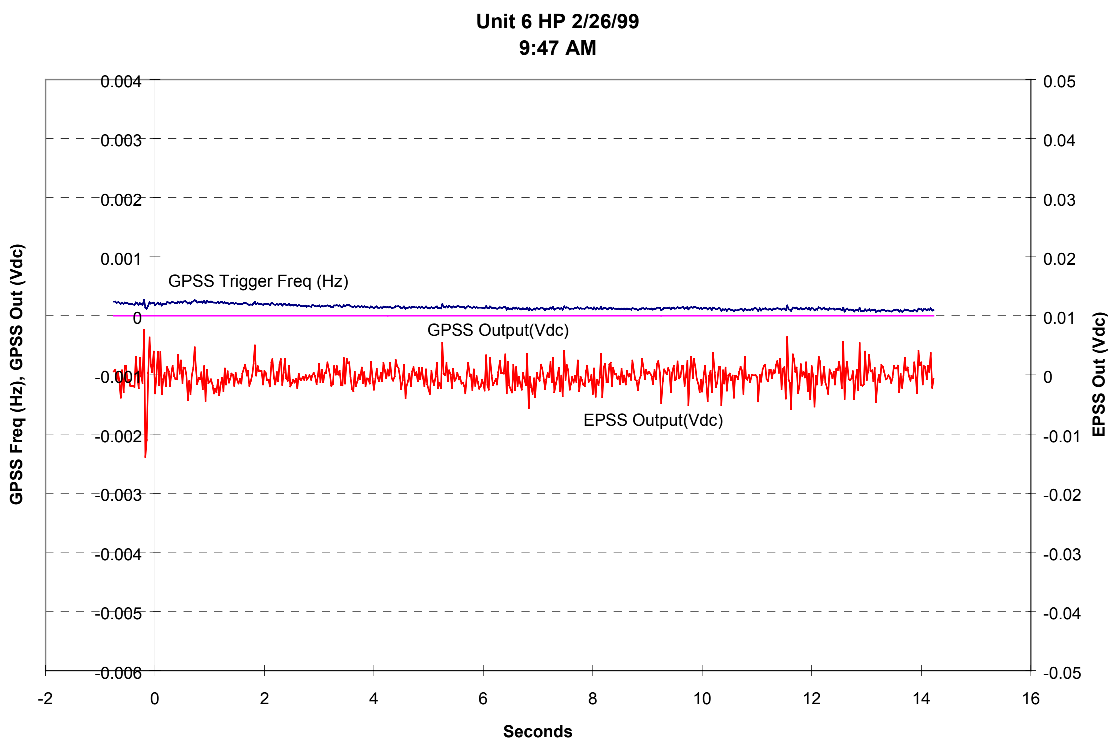



Unit 6 HP 2/26/99
9:42 AM
Magnitude
250
200
150
100
50
0
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
-2
0
2
4
6
8
10
12
14
16
Seconds

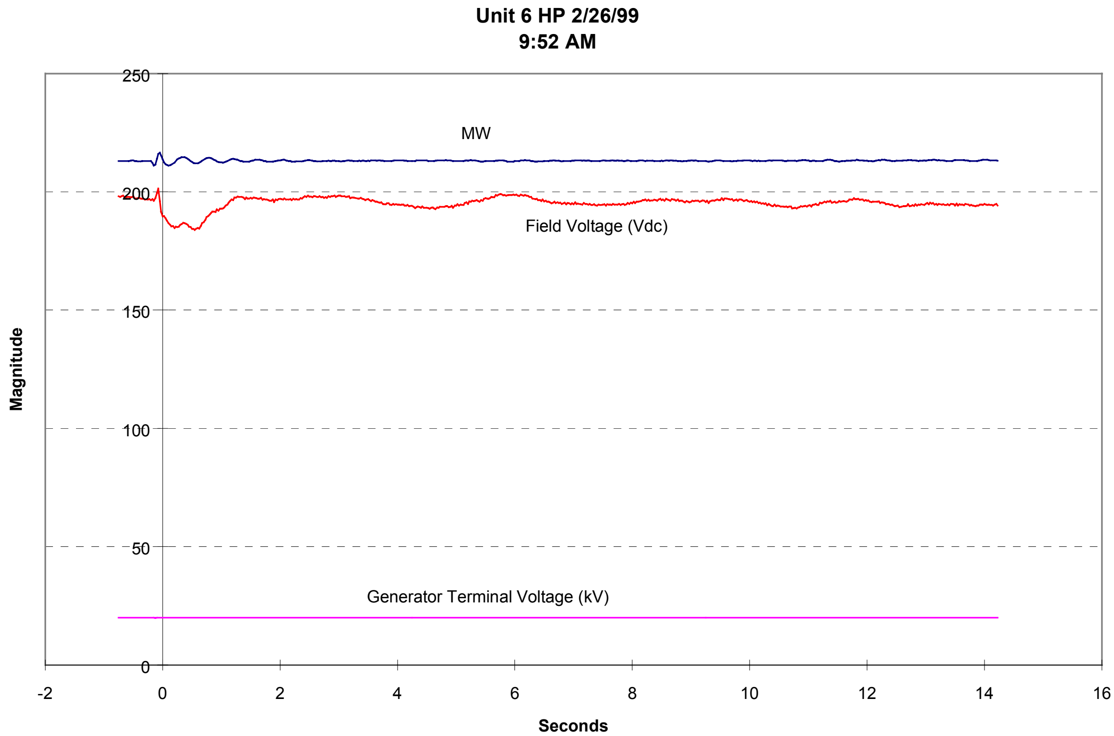

Unit 6 HP 2/26/99
9:42 AM
GPSS Freq (Hz), GPSS Out (Vdc)
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
EPSS Out (Vdc)
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
-2
0
2
4
6
8
10
12
14
16
Seconds



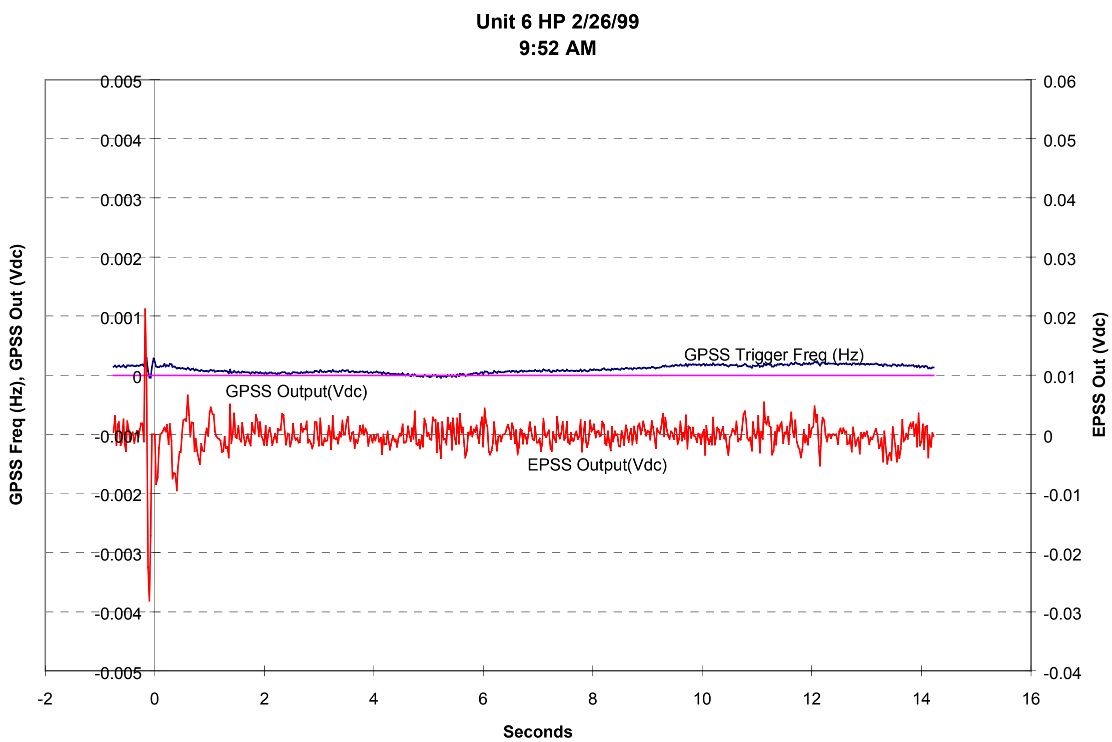
Unit 6 HP 2/26/99
9:47 AM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Seconds
250
200
150
100
50
0
-2
0
2
4
6
8
10
12
14
16



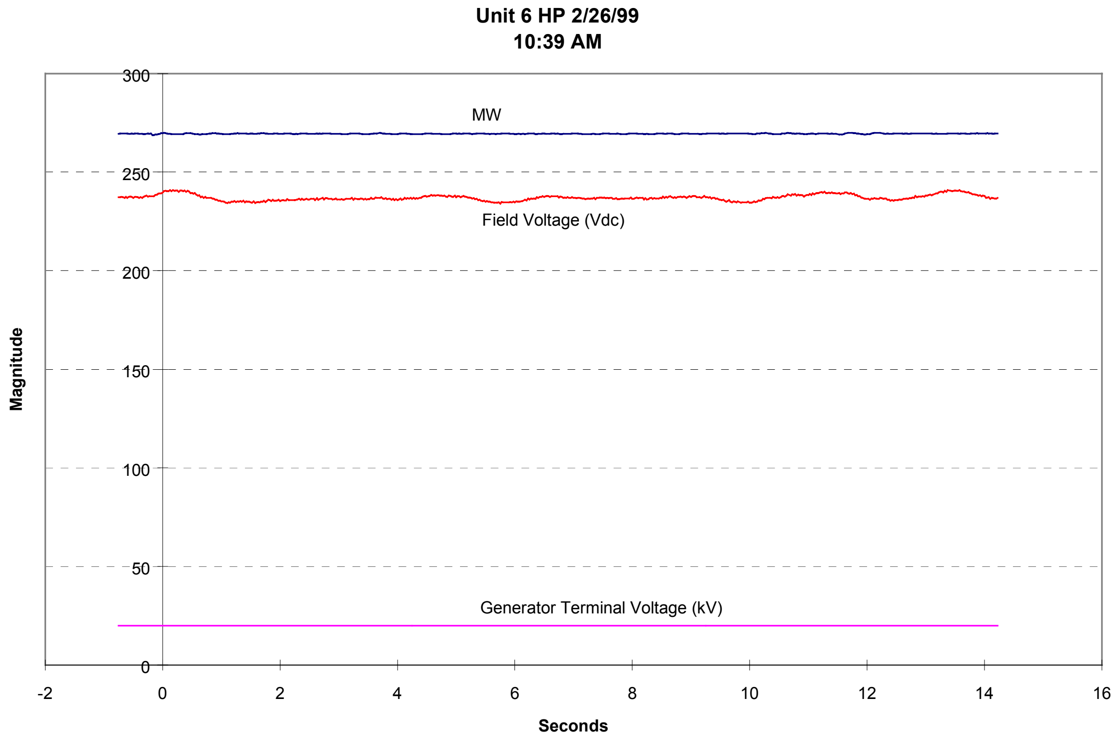
Unit 6 HP 2/26/99
9:47 AM
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-2
0
2
4
6
8
10
12
14
16

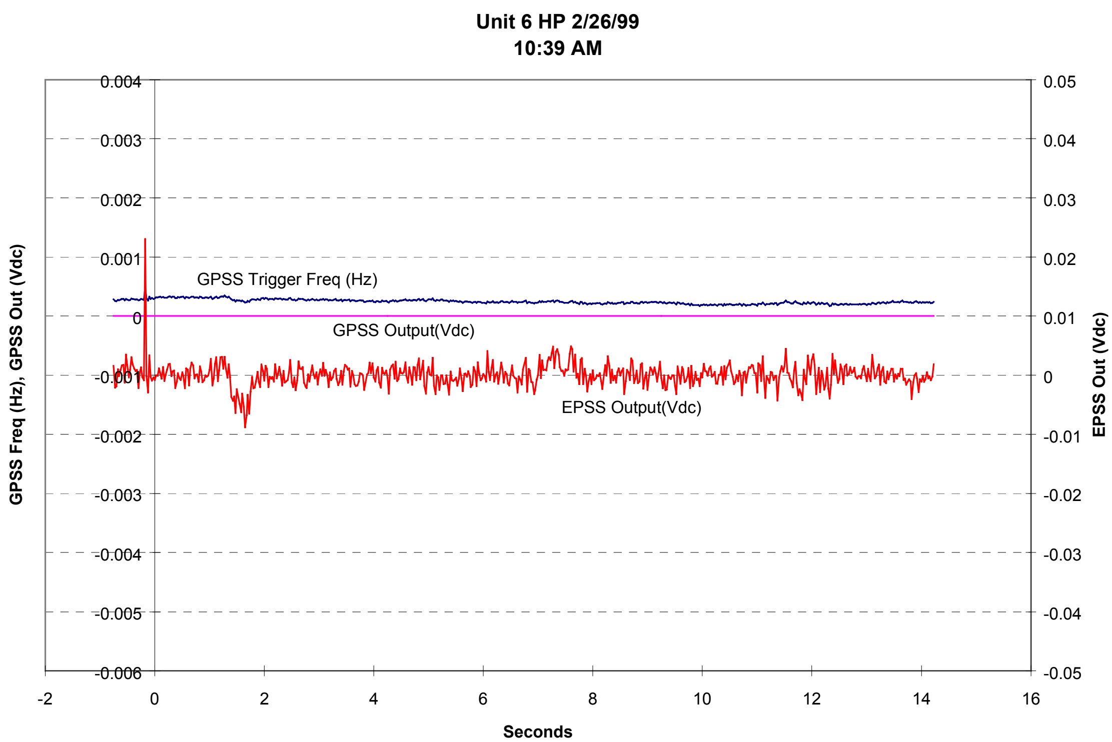


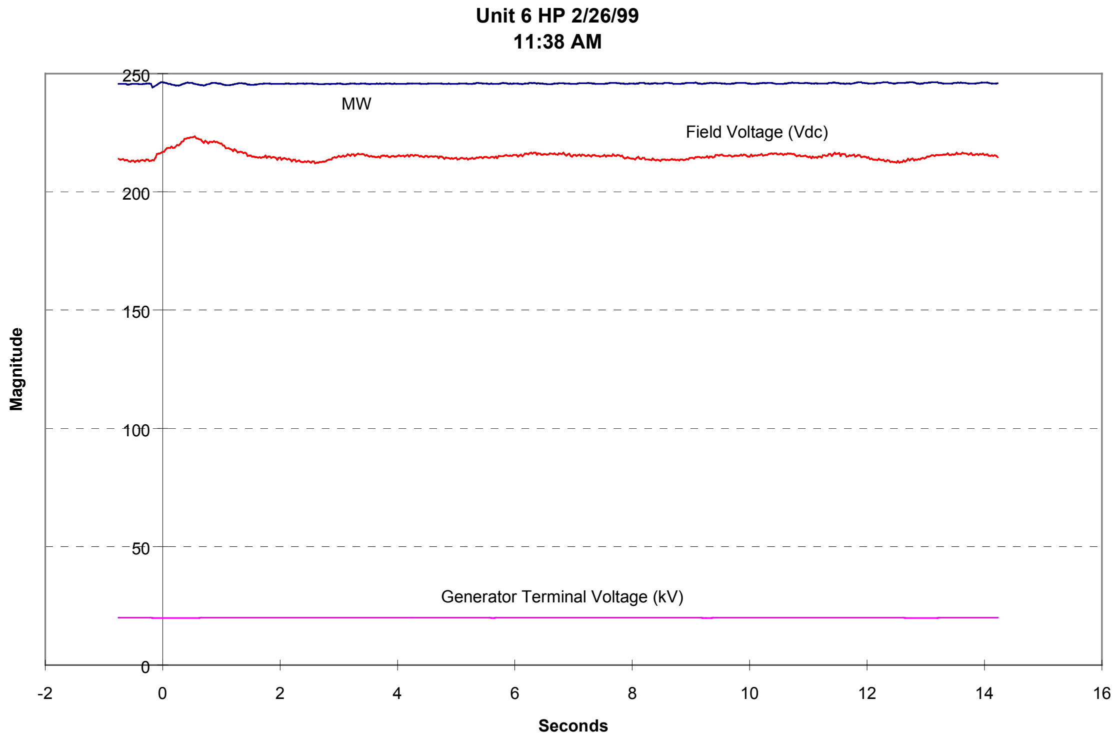
Unit 6 HP 2/26/99
9:52 AM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Seconds
250
200
150
100
50
0
-2
0
2
4
6
8
10
12
14
16

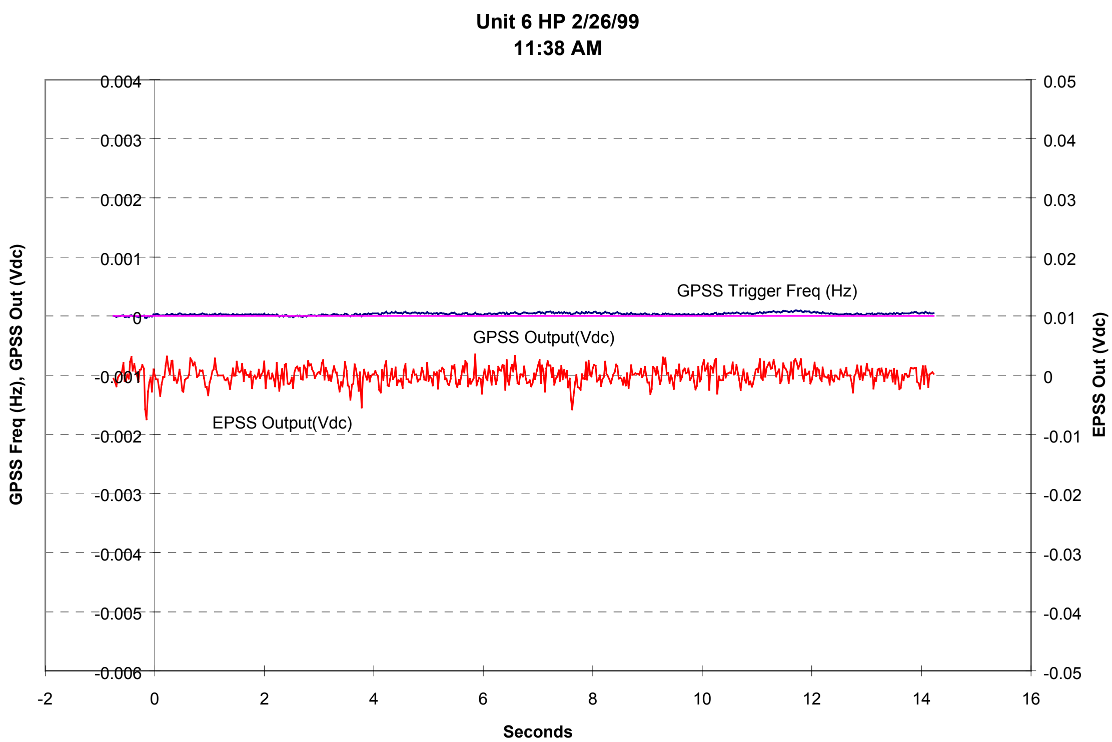


Unit 6 HP 2/26/99
9:52 AM
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

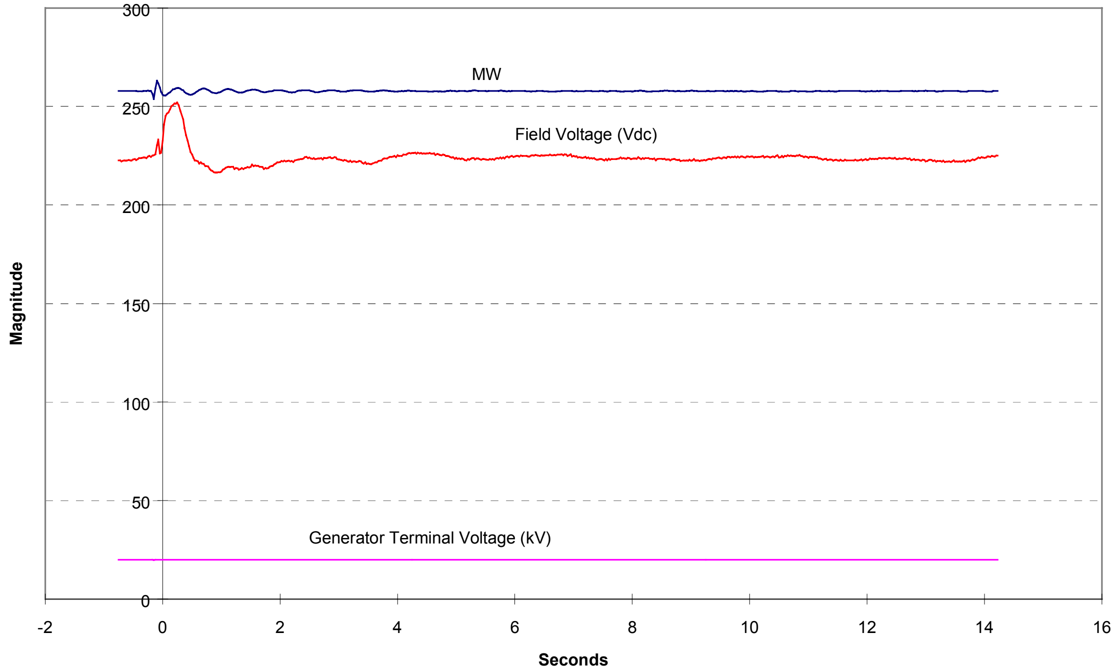

Unit 6 HP 2/26/99
10:39 AM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Seconds
300
250
200
150
100
50
0
-2
0
2
4
6
8
10
12
14
16


Unit 6 HP 2/26/99
10:39 AM
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-2
0
2
4
6
8
10
12
14
16

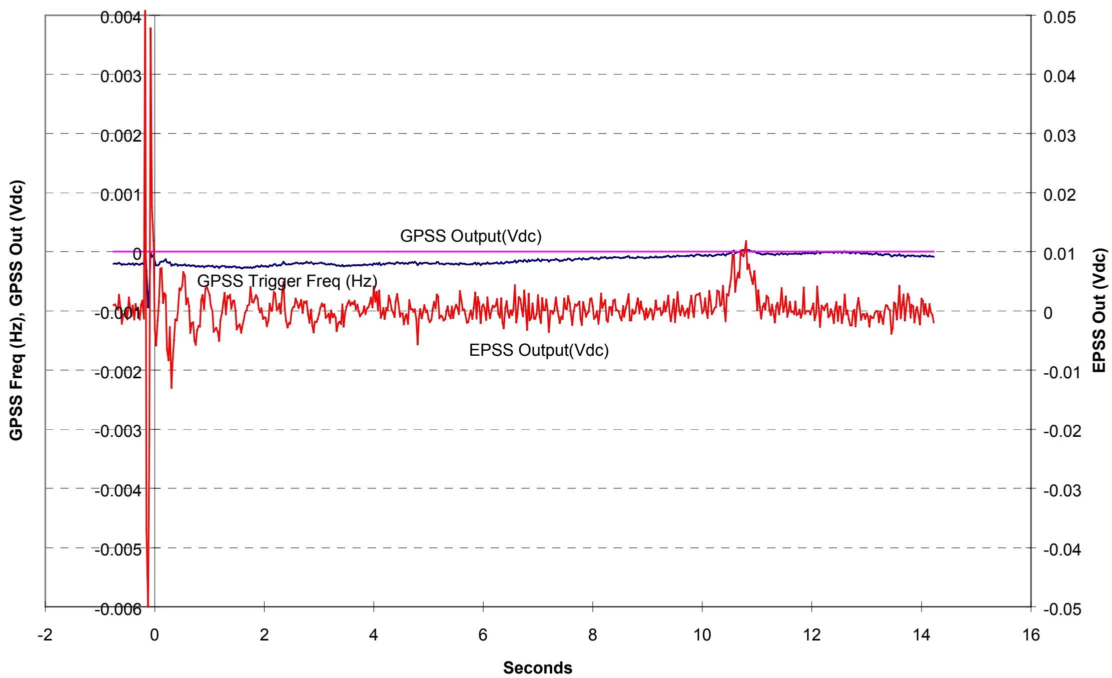

Unit 6 HP 2/26/99
11:38 AM
250
200
150
100
50
0
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
-2
0
2
4
6
8
10
12
14
16
Seconds

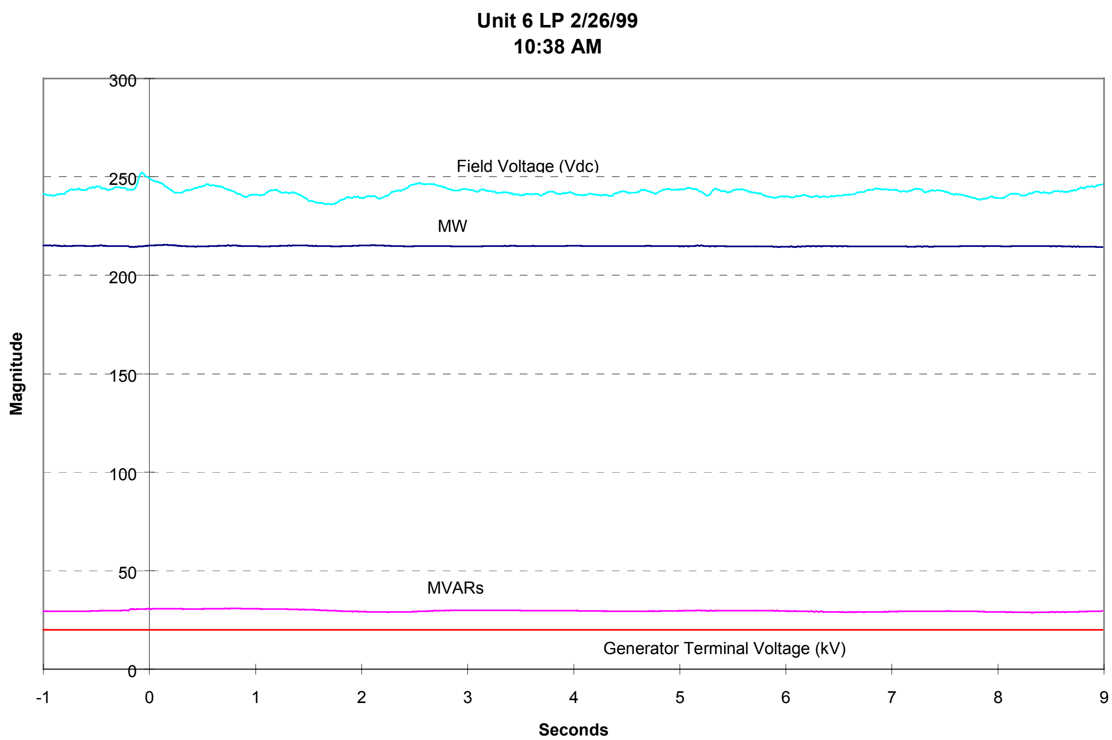

Unit 6 HP 2/26/99
11:38 AM
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
-2
0
2
4
6
8
10
12
14
16
Seconds

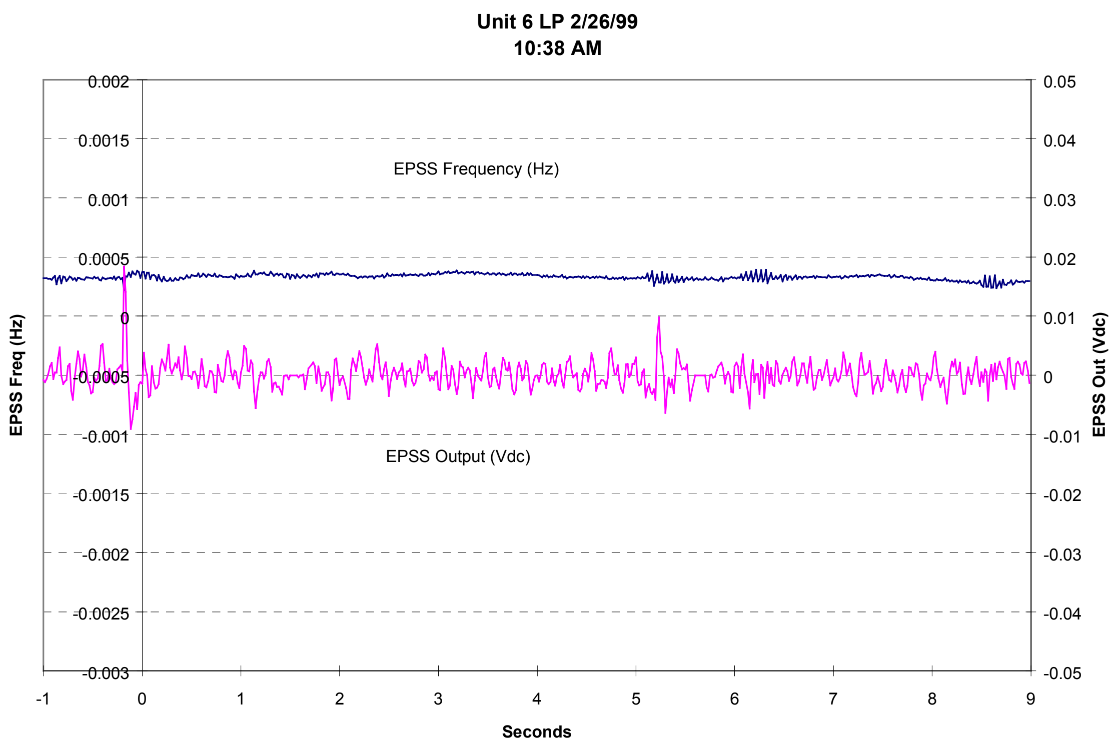
Unit 6 HP 2/26/99
11:53 AM



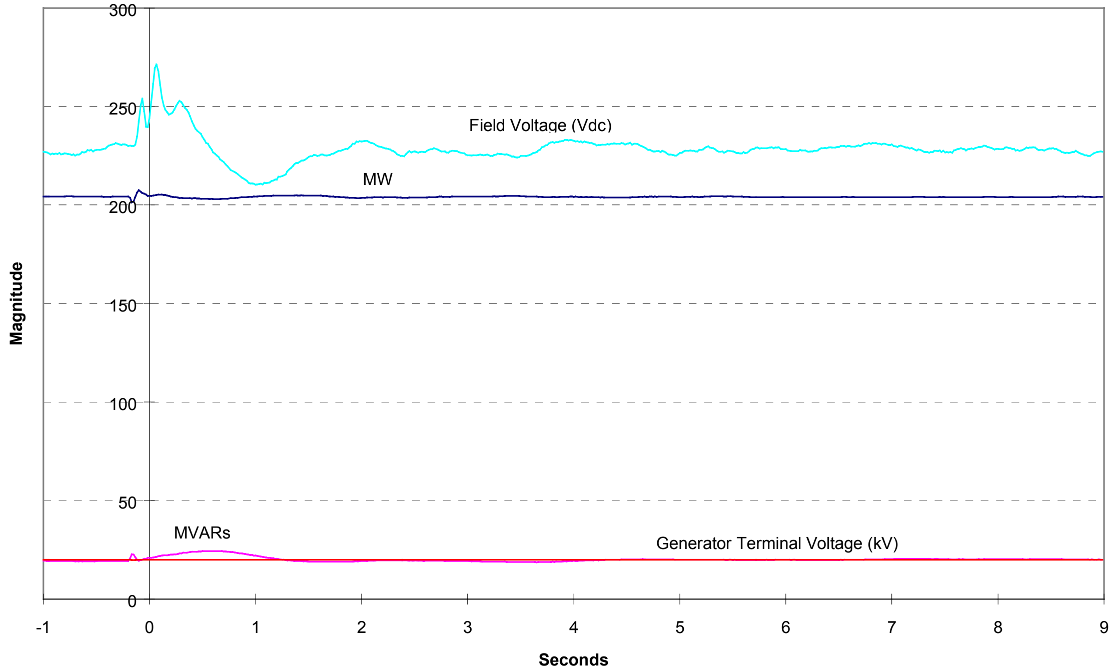
Unit 6 HP 2/26/99
11:53 AM



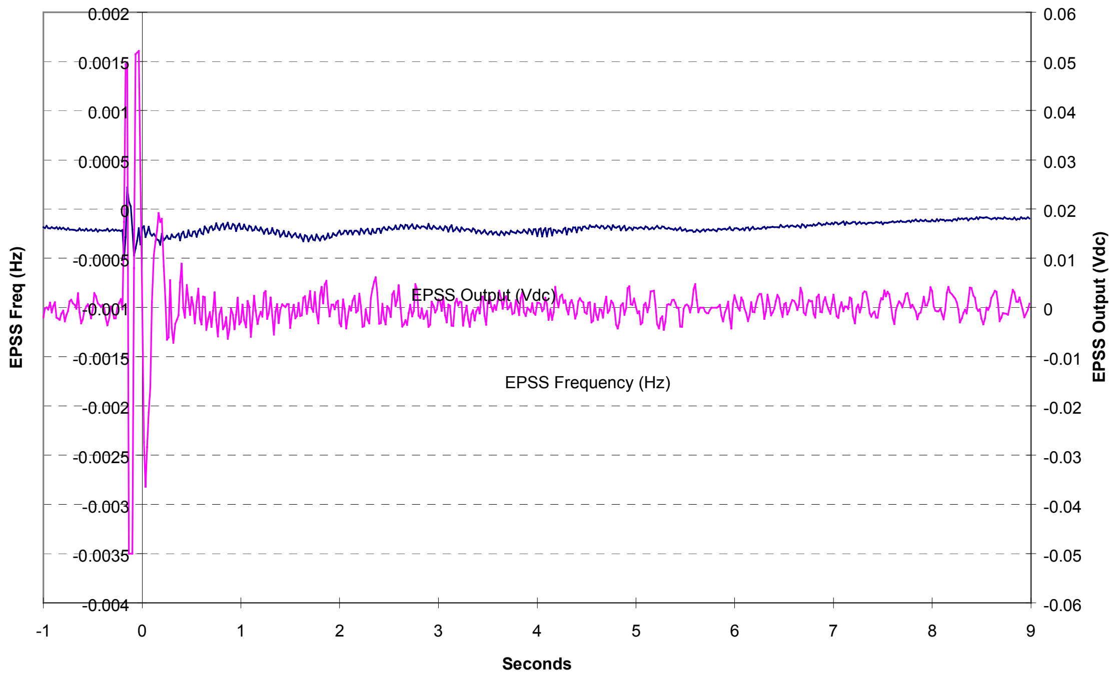

Unit 6 LP 2/26/99
10:38 AM
Field Voltage (Vdc)
MW
MVARs
Generator Terminal Voltage (kV)
Magnitude
Seconds
300
250
200
150
100
50
0
-1
0
1
2
3
4
5
6
7
8
9

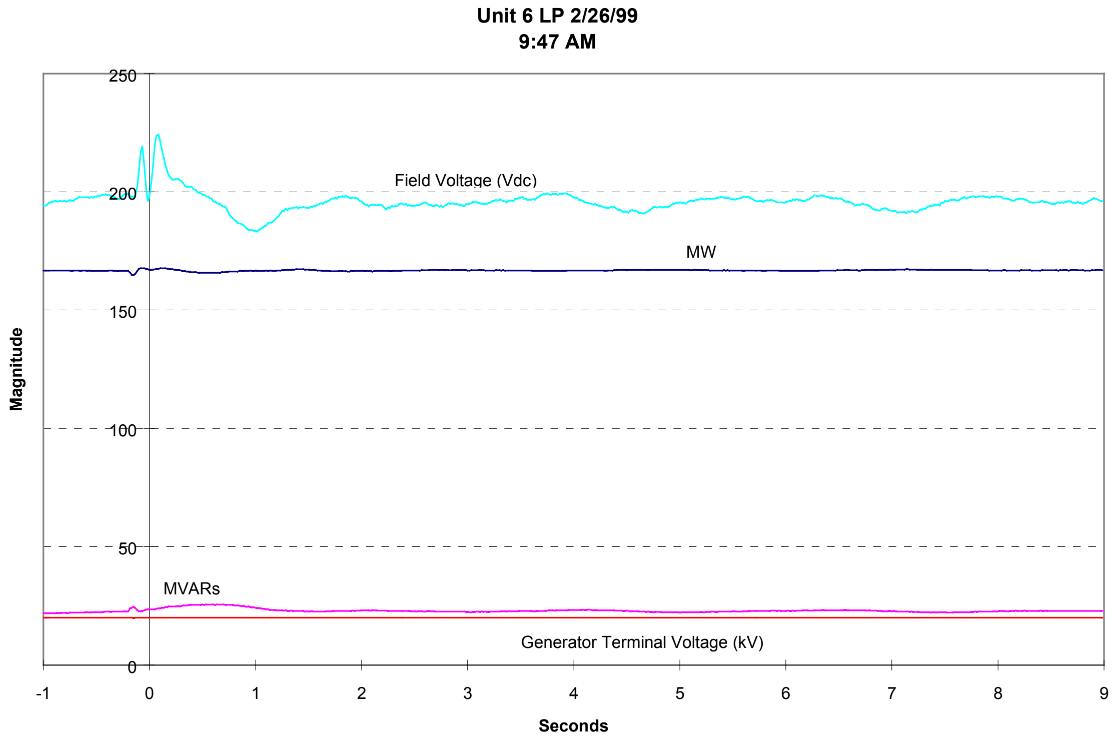

Unit 6 LP 2/26/99
10:38 AM
EPSS Frequency (Hz)
EPSS Output (Vdc)
EPSS Freq (Hz)
EPSS Out (Vdc)
Seconds
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-0.0025
-0.003
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-1
0
1
2
3
4
5
6
7
8
9

Unit 6 LP 2/26/99
11:59 AM

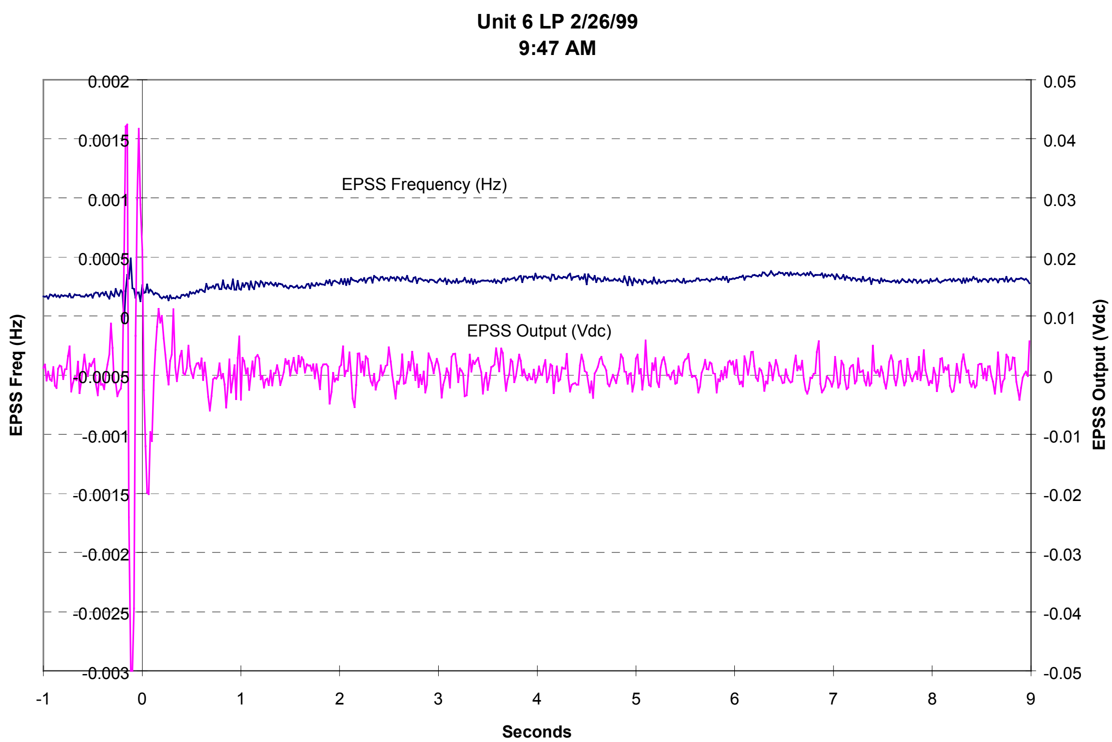


Unit 6 LP 2/26/99
11:59 AM

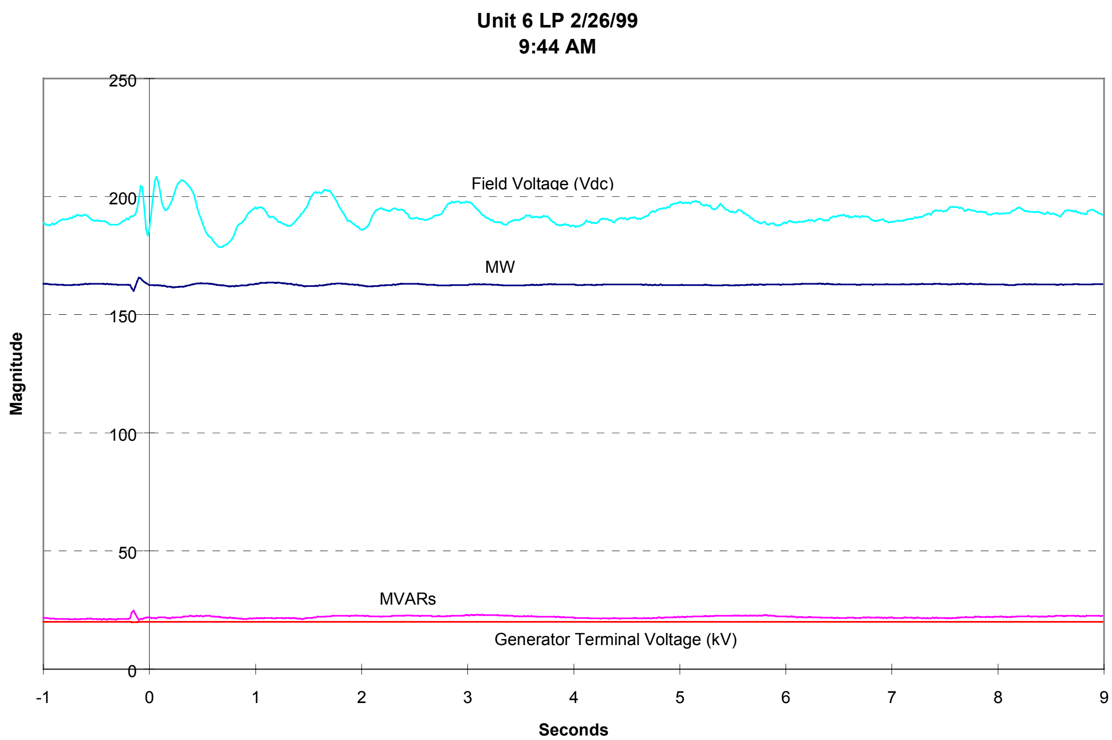


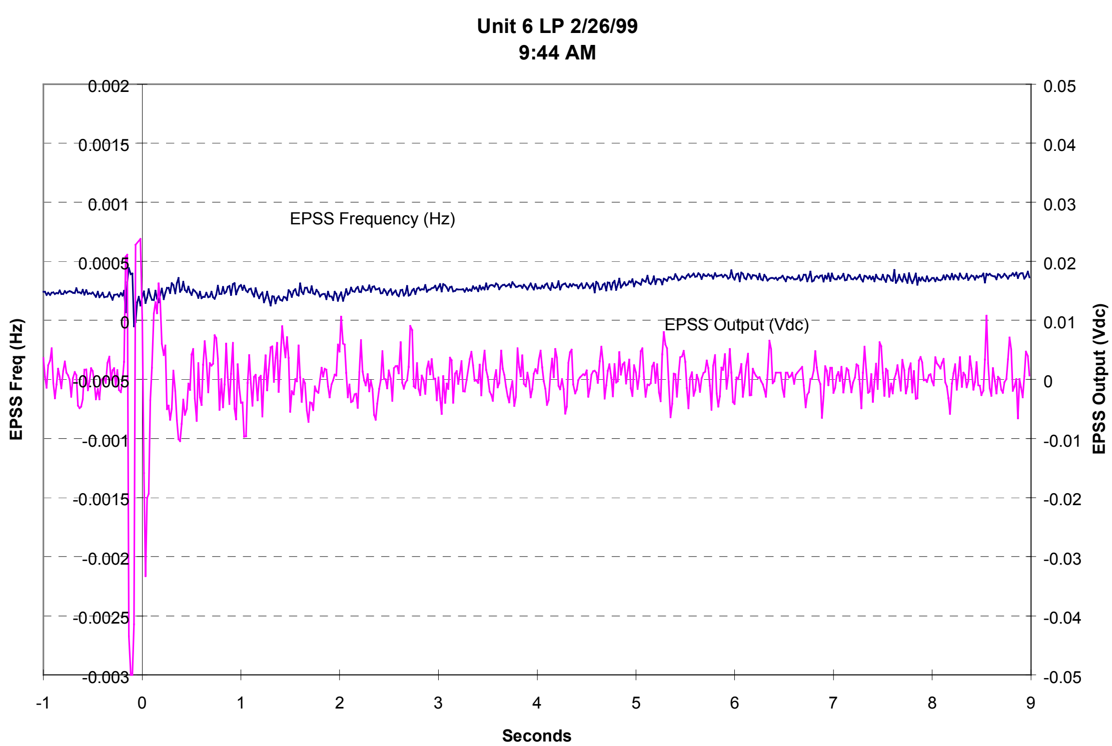


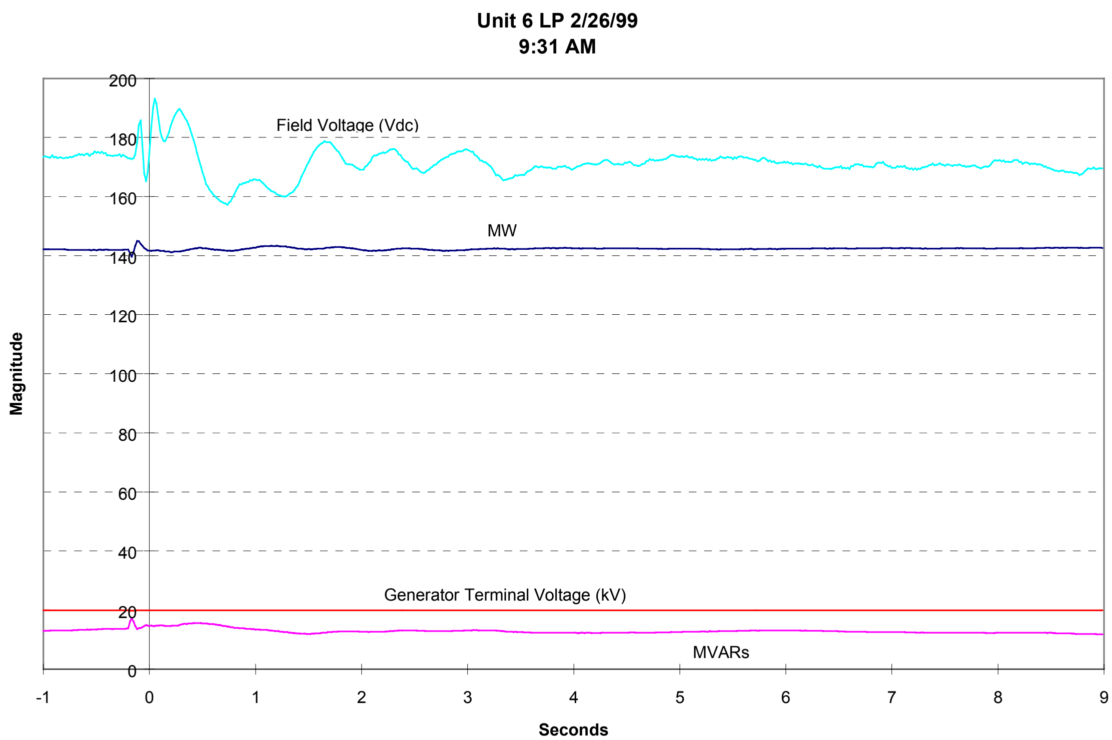
Unit 6 LP 2/26/99
9:47 AM
Field Voltage (Vdc)
MW
MVARs
Generator Terminal Voltage (kV)
Magnitude
Seconds
250
200
150
100
50
0
-1
0
1
2
3
4
5
6
7
8
9



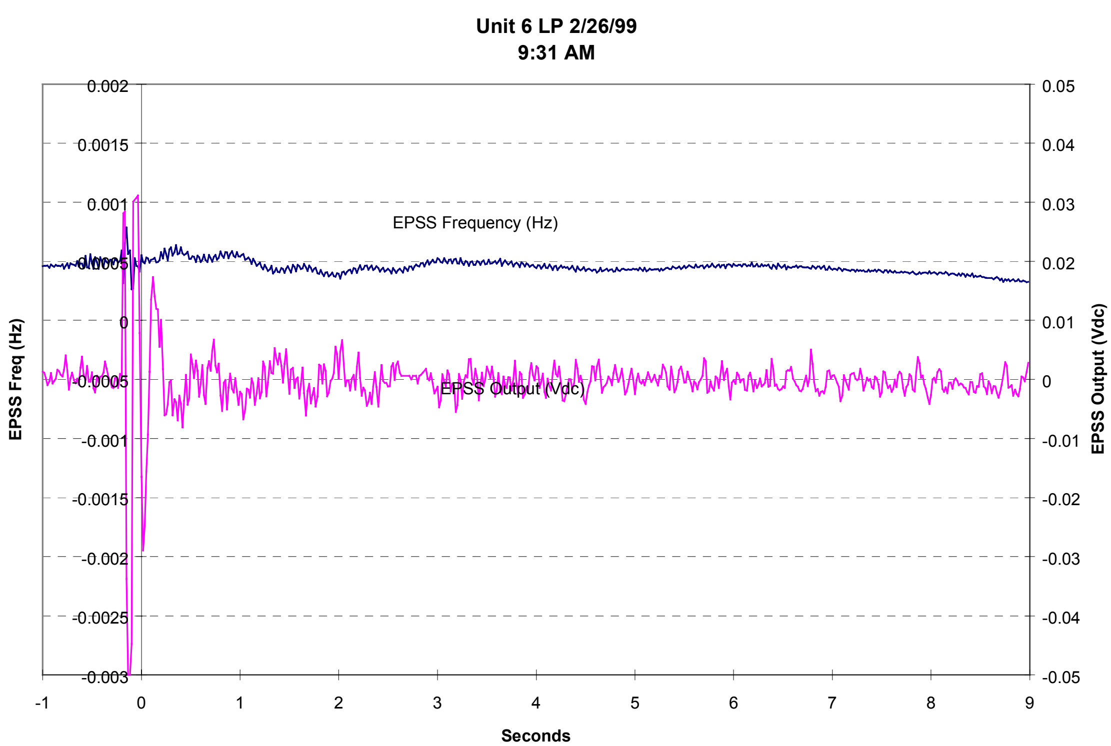
Unit 6 LP 2/26/99
9:47 AM
EPSS Frequency (Hz)
EPSS Output (Vdc)
EPSS Freq (Hz)
EPSS Output (Vdc)
Seconds
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-0.0025
-0.003
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 2/26/99
9:44 AM
Field Voltage (Vdc)
MW
MVARs
Generator Terminal Voltage (kV)
Magnitude
Seconds
250
200
150
100
50
0
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 2/26/99
9:44 AM
EPSS Frequency (Hz)
EPSS Output (Vdc)
EPSS Freq (Hz)
EPSS Output (Vdc)
Seconds
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-0.0025
-0.003
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-1
0
1
2
3
4
5
6
7
8
9



Unit 6 LP 2/26/99
9:31 AM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
MVARs
Magnitude
Seconds
200
180
160
140
120
100
80
60
40
20
0
-1
0
1
2
3
4
5
6
7
8
9



Unit 6 LP 2/26/99
9:31 AM
EPSS Frequency (Hz)
EPSS Output (Vdc)
EPSS Freq (Hz)
EPSS Output (Vdc)
Seconds
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-0.0025
-0.003
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-1
0
1
2
3
4
5
6
7
8
9

Appendix VIII
Data Collected for Unit 6 After 2/26/99

Unit: 6
Date of Work: 2/26/99 – 3/24/99

Brief Description of Work Performed

ESI engineering personnel downloaded data on 3/24/99 to collect the data records for the previous month's operation. Charts of selected data are included in the attachments to this report. The electrical power system stabilizer (EPSS) portion of the IPSS for both the HP and LP generators have triggered several data records, although the unit has been down for most of March. The governor power system stabilizer (GPSS) portion of the IPSS on the HP generator has not yet triggered and operated.

The charts include the MW load, the generator terminal voltage, the field voltage, GPSS trigger signal, GPSS output, EPSS sensing frequency, and EPSS output where applicable.

HP GPSS and EPSS Settings

The operating parameters for the GPSS and EPSS as well as the data recorder settings for the HP generator are tabulated below. Those marked with an asterisk have been changed since the last report.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~42 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS power-on threshold (p.u. MVA)	0.36	~100 MW
GPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS turn-on frequency (Hz)	0.02	
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	5	0.75 seconds
Number half cycles between logger saves	3	15 second record
Autotrigger Values		
p.u. GPSS Trigger setpoint (Hz)	0.02*	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	20*	0.166 seconds
Priority	3	
EPSS Output	0.02	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	60*	0.500 seconds
Priority	2	

LP EPSS Settings

The operating parameters for the EPSS as well as the data recorder settings for the LP generator are tabulated below. Those marked with an asterisk have been changed since the last report.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~33 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~11 MW
GPSS power-on threshold (p.u. MVA)	1.0	No GPSS
GPSS power-on MVA hysteresis (p.u. MVA)	0	

On/Off Control	Setting	Comment
GPSS turn-on frequency (Hz)	0.5	
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	10	1.0 seconds
Number half cycles between logger saves	2	10 second record
Autotrigger Values		
EPSS Output	0.02 *	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	20	0.166 seconds
Priority	2	

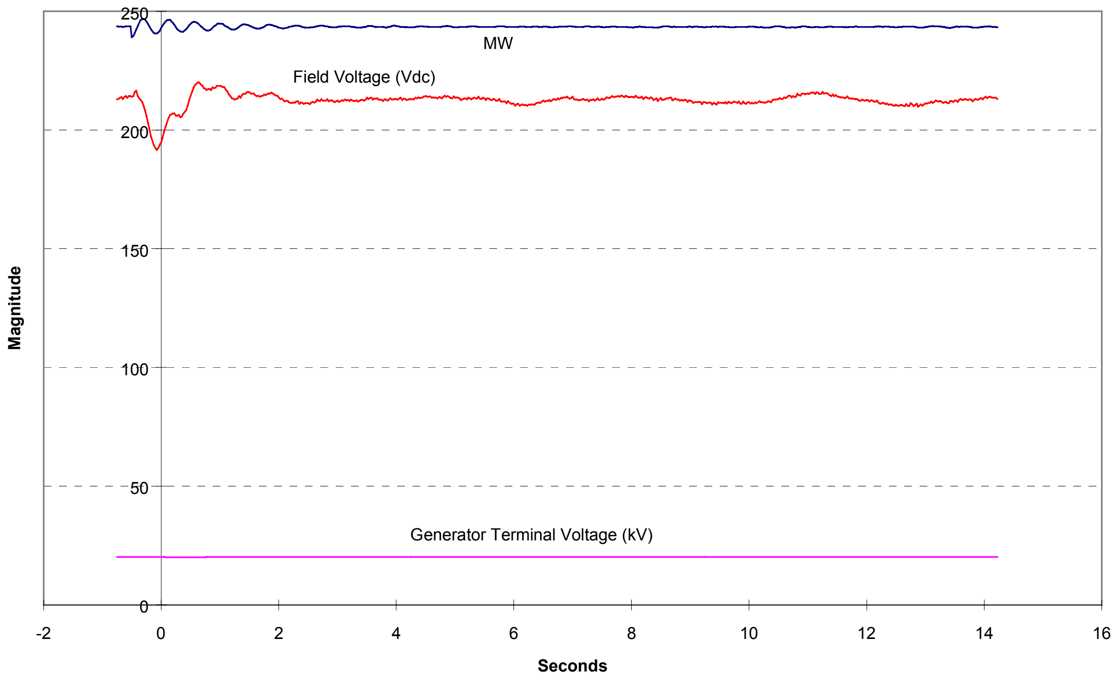
Observations

The MW load for all HP included data records during the events captured in late February and March 1999 are all above the ON enable setpoint of 0.36 p.u. or 100 MW for any GPSS operation. However, the data records indicate the GPSS trigger frequency never approached the 0.02 Hz turn on threshold. One LP data record is included to demonstrate operation of LP EPSS.

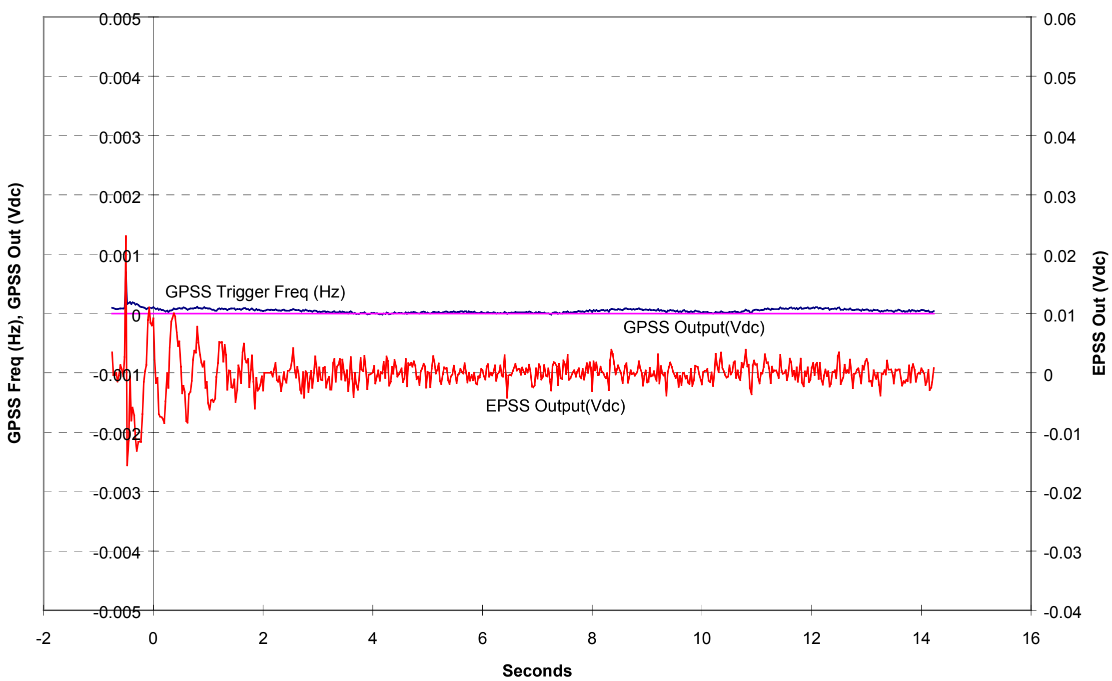
The data recorder trigger threshold for the GPSS will be reset to a lower value in incremental steps until a data record is obtained for a GPSS trigger indication. The actual GPSS trigger setpoint will remained unchanged and will operate only if the frequency excursion exceeds the 0.02 Hz threshold. The data will be evaluated prior to making any actual operational changes.

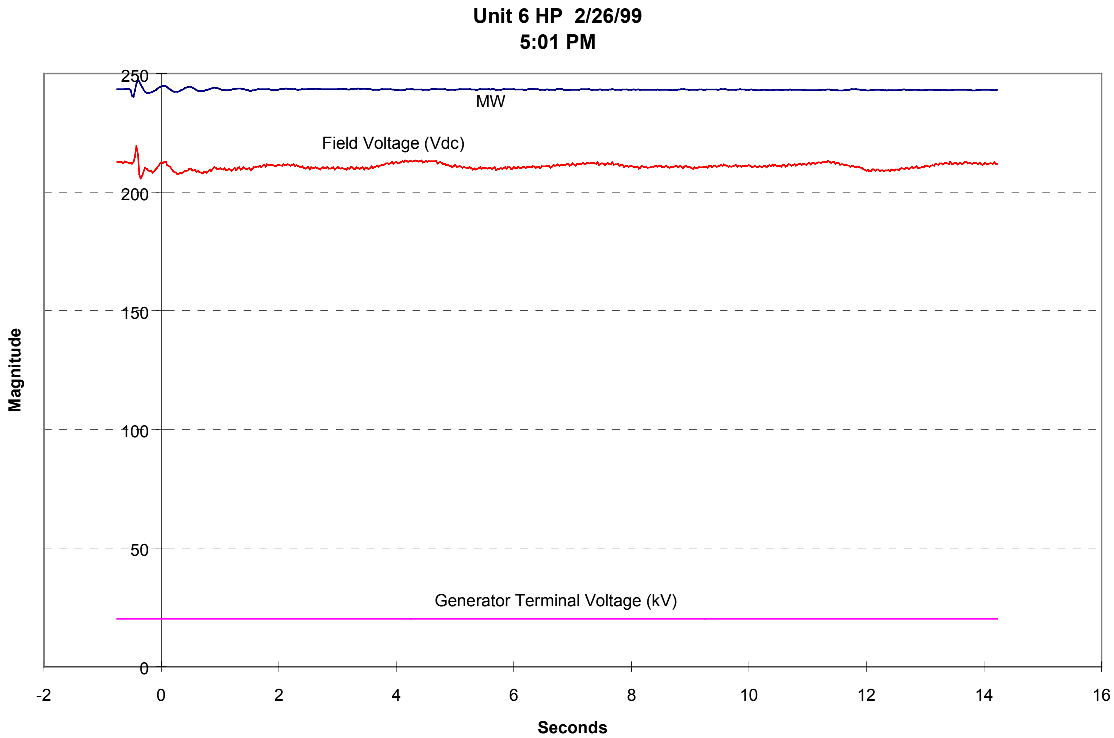
Attachments

Unit 6 HP 2/26/99
5:00 PM

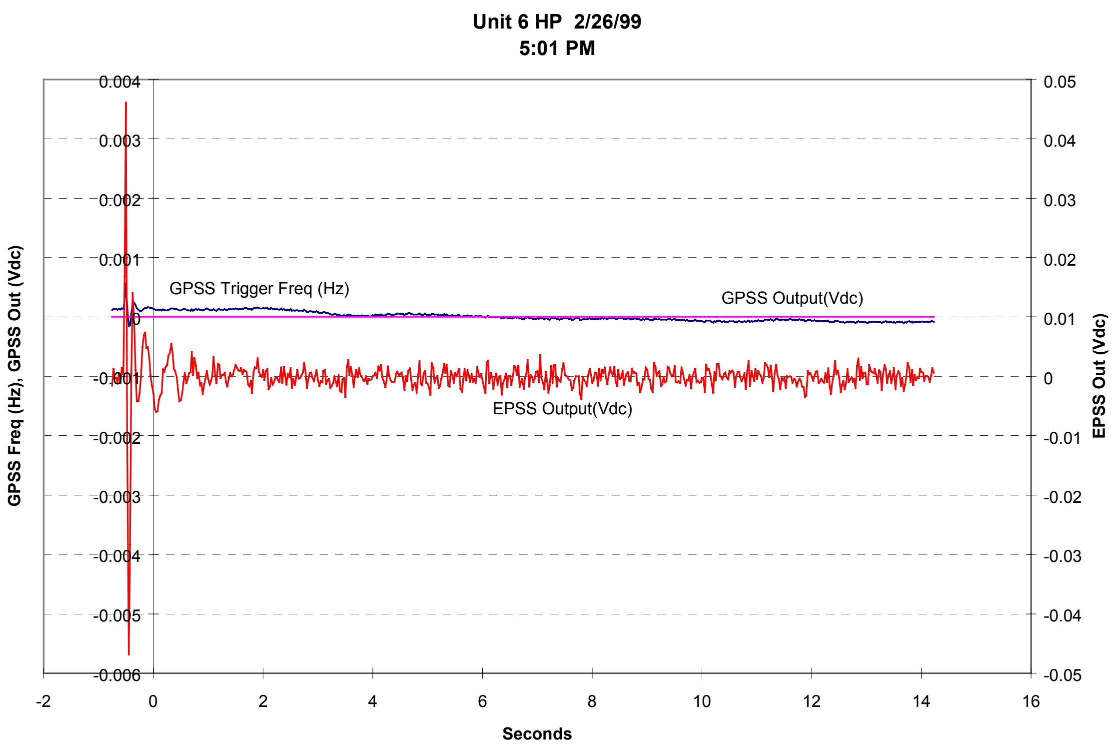


Unit 6 HP 2/26/99
5:00 PM

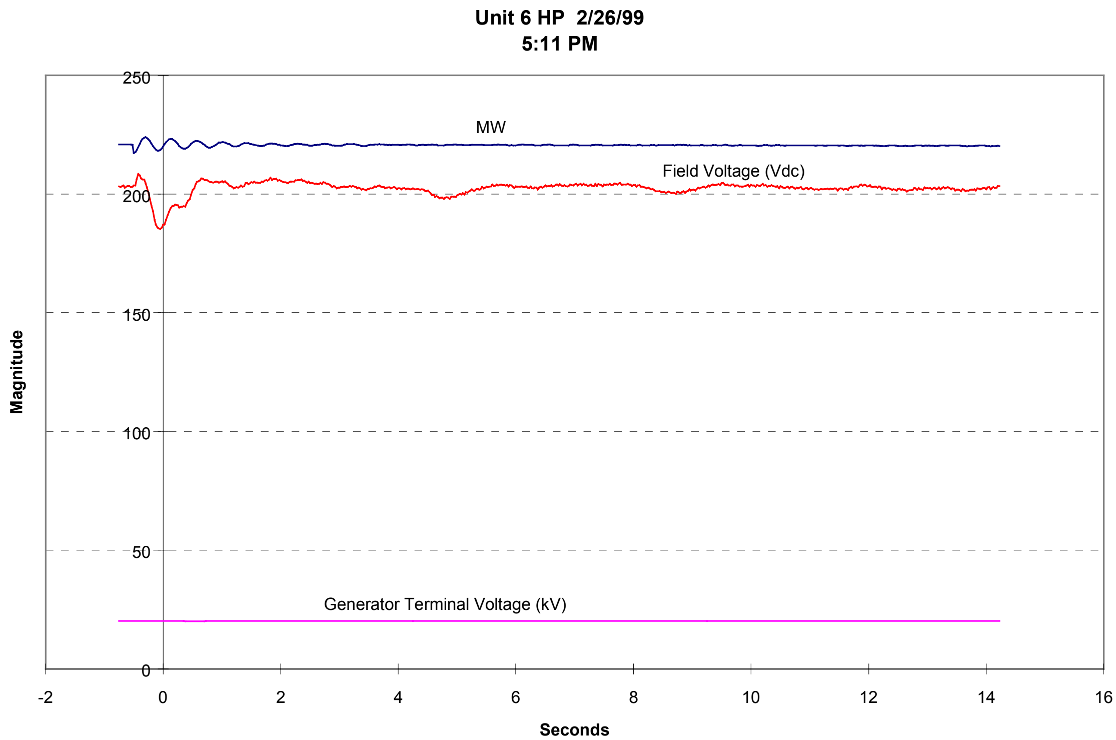


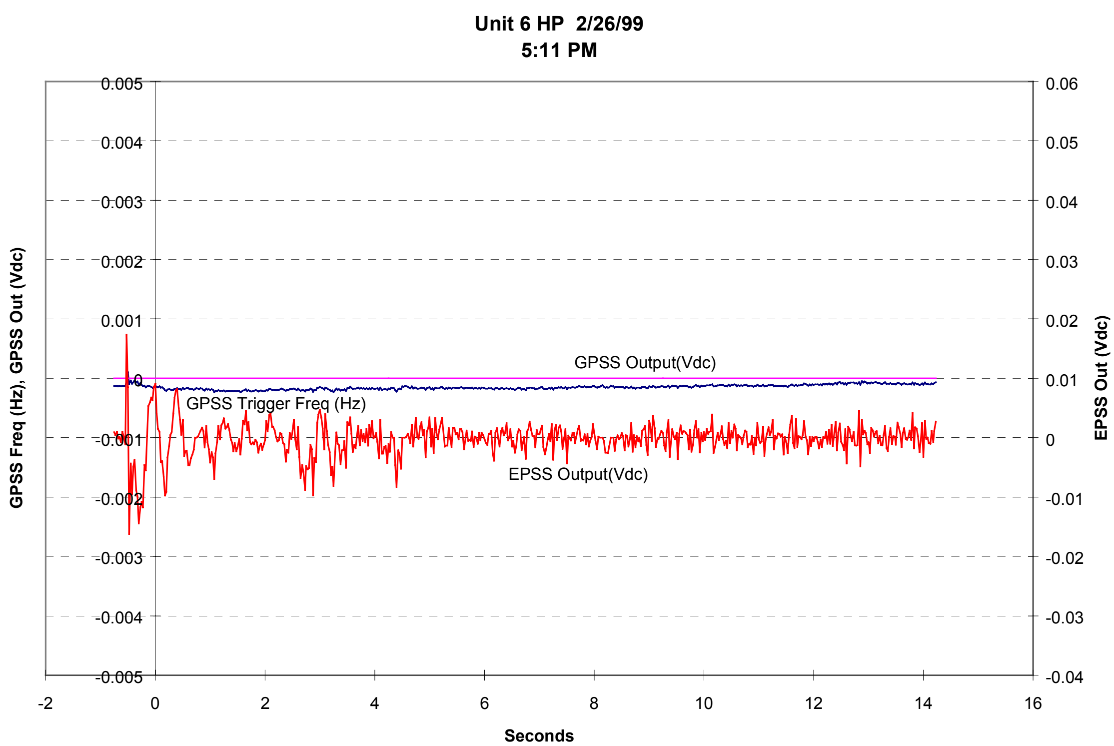


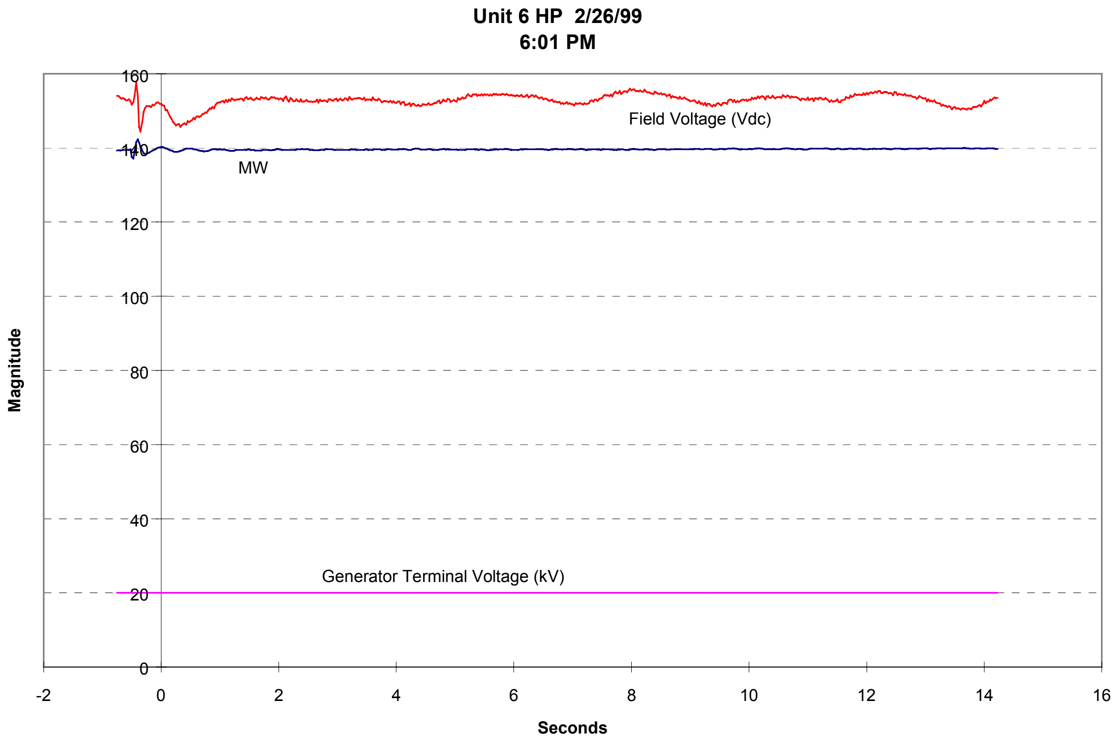
Unit 6 HP 2/26/99
5:01 PM
250
200
150
100
50
0
-2
0
2
4
6
8
10
12
14
16
Magnitude
Seconds
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)

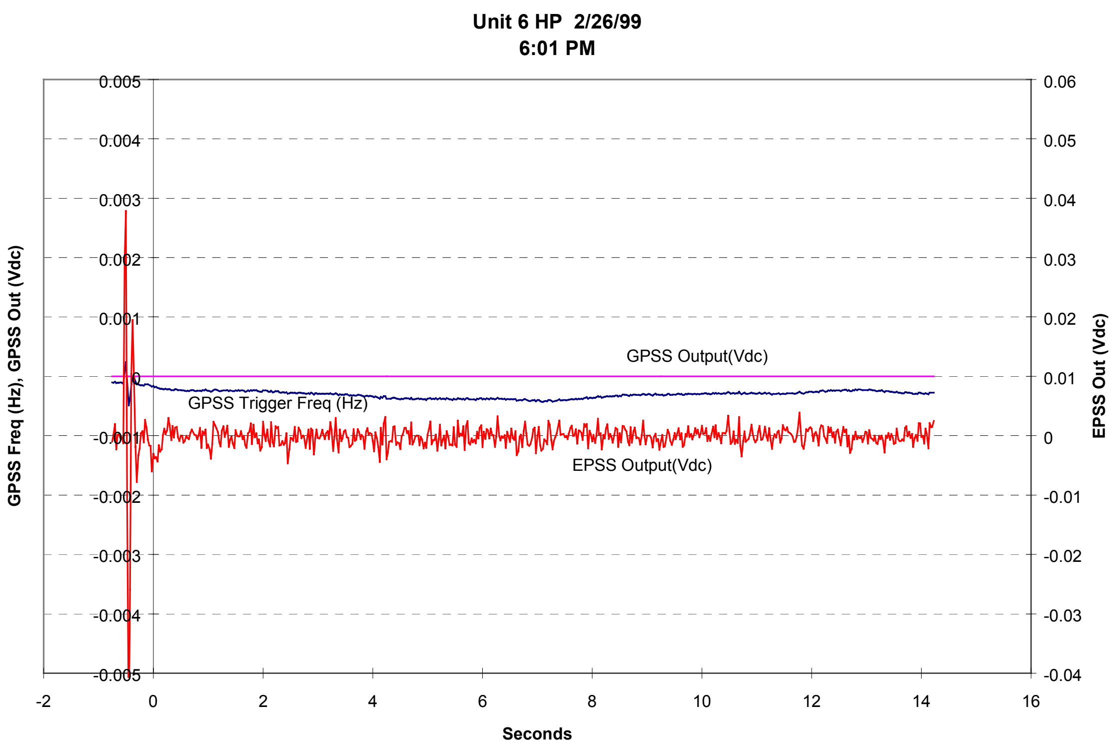


Unit 6 HP 2/26/99
5:01 PM
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-2
0
2
4
6
8
10
12
14
16
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)

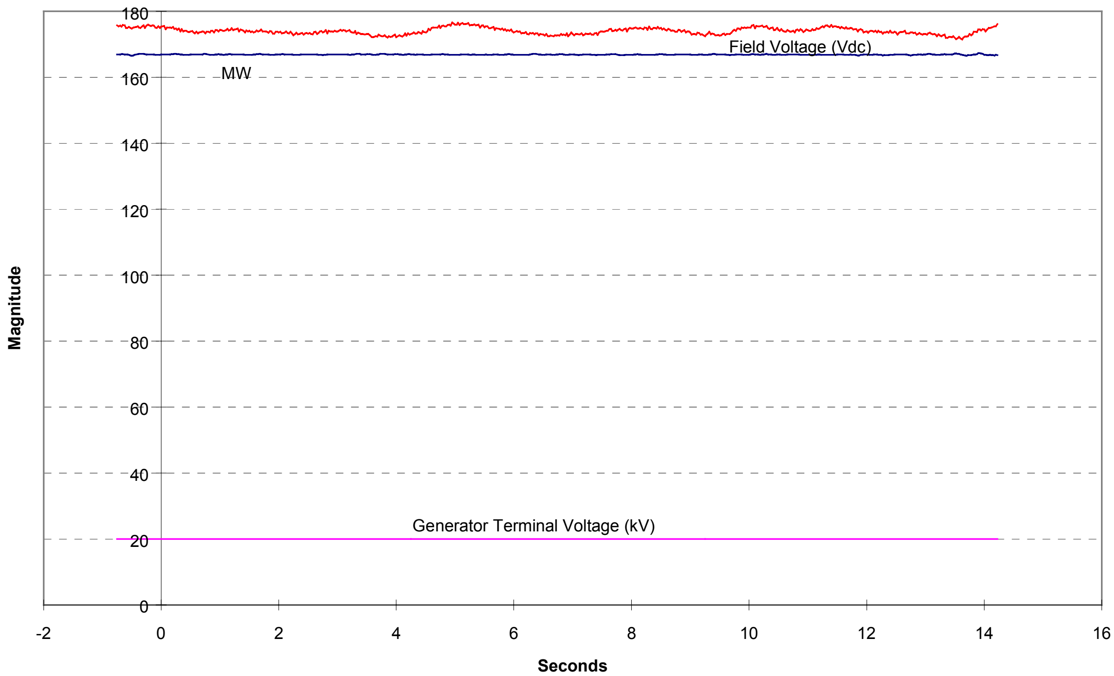

Unit 6 HP 2/26/99
5:11 PM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Seconds
250
200
150
100
50
0
-2
2
4
6
8
10
12
14
16


Unit 6 HP 2/26/99
5:11 PM
GPSS Output(Vdc)
GPSS Trigger Freq (Hz)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
0.06
0.05
0.04
0.03
0.02
0.01
-0.01
-0.02
-0.03
-0.04
-2
2
4
6
8
10
12
14
16

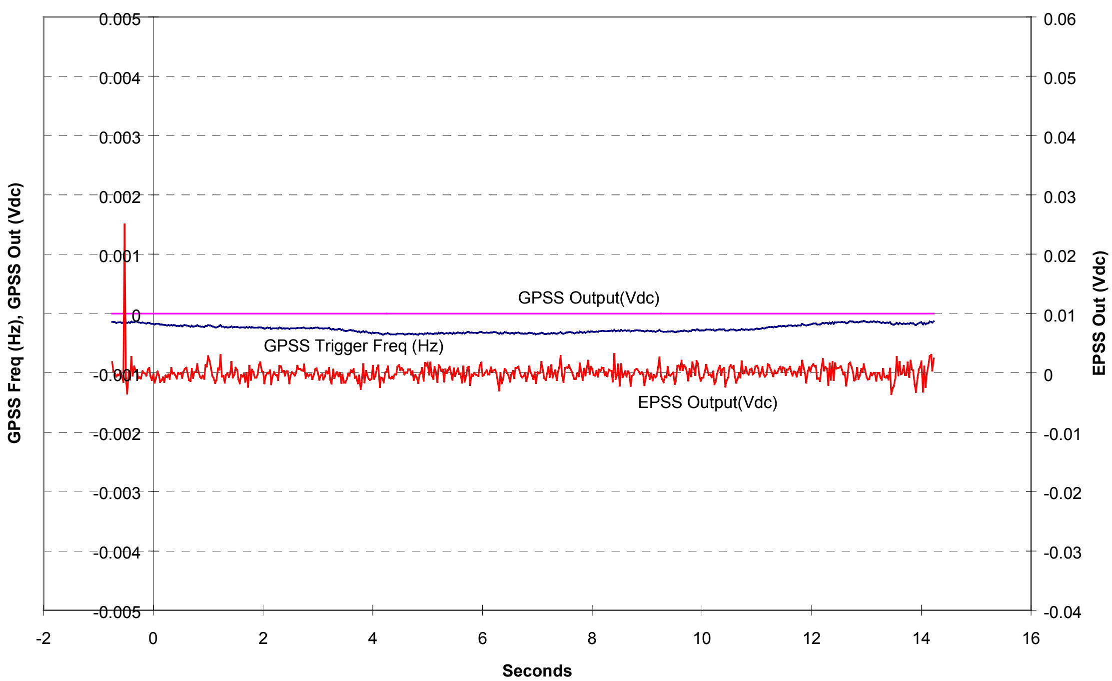

Unit 6 HP 2/26/99
6:01 PM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
Magnitude
Seconds

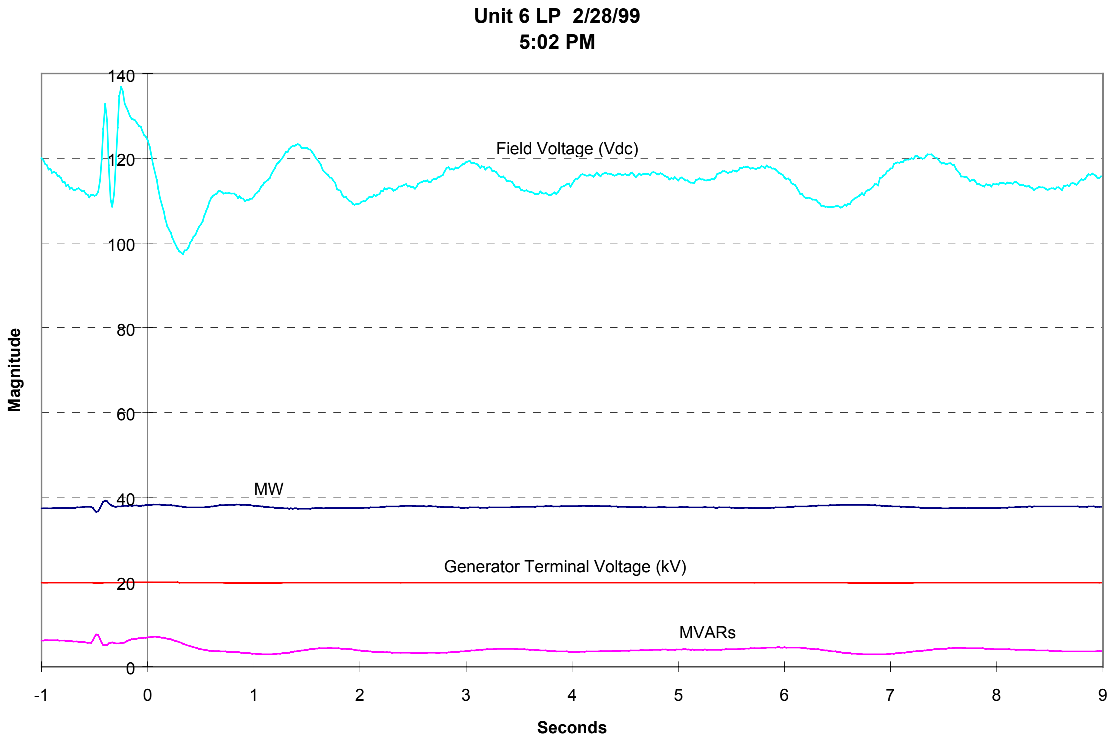

Unit 6 HP 2/26/99
6:01 PM
GPSS Output(Vdc)
GPSS Trigger Freq (Hz)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds

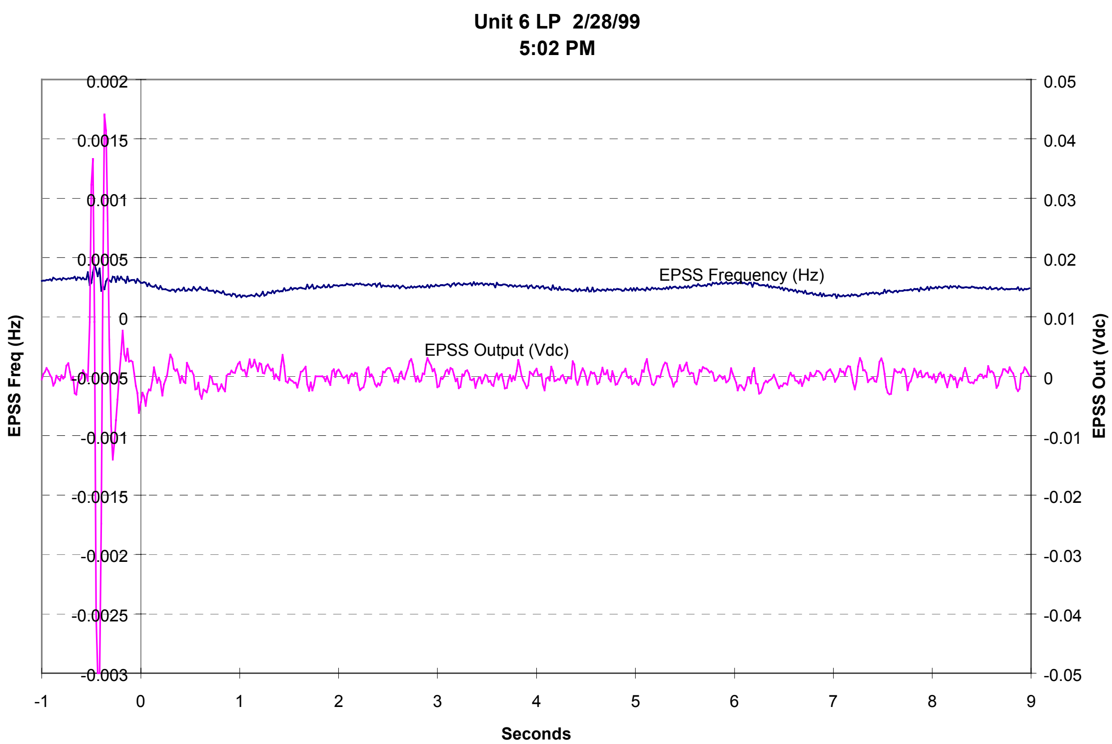
Unit 6 HP 2/26/99
6:20 PM



Unit 6 HP 2/26/99
6:20 PM




Unit 6 LP 2/28/99
5:02 PM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
MVARs
Magnitude
Seconds
140
120
100
80
60
40
20
0
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 2/28/99
5:02 PM
EPSS Frequency (Hz)
EPSS Output (Vdc)
EPSS Freq (Hz)
EPSS Out (Vdc)
Seconds
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-0.0025
-0.003
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-1
0
1
2
3
4
5
6
7
8
9

Appendix IX
Data Collected for Unit 6 After 3/25/99

Unit: 6
Date of Work: 3/25/99 – 5/4/99

Brief Description of Work Performed

ESI engineering personnel downloaded data on 4/12/99 and 5/4/99 to collect the data records for the previous 2 months operation. Charts of selected data are included in the attachments to this report. The electrical power system stabilizer (EPSS) portion of the IPSS for both the HP and LP generators have triggered several data records. The governor power system stabilizer (GPSS) portion of the IPSS on the HP generator has not yet triggered and operated.
The charts include the MW load, the generator terminal voltage, the field voltage, GPSS trigger signal, GPSS output, EPSS sensing frequency, and EPSS output where applicable.

HP GPSS and EPSS Settings

The operating parameters for the GPSS and EPSS as well as the data recorder settings for the HP generator are tabulated below. Those marked with an asterisk have been changed since the last report.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~42 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS power-on threshold (p.u. MVA)	0.36	~100 MW
GPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS turn-on frequency (Hz)	0.02	
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	5	0.75 seconds
Number half cycles between logger saves	3	15 second record
Autotrigger Values		
p.u. GPSS Trigger setpoint (Hz)	0.005*	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	20	0.166 seconds
Priority	3	
EPSS Output	0.02	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	120*	1.00 seconds
Priority	2	

LP EPSS Settings

The operating parameters for the EPSS as well as the data recorder settings for the LP generator are tabulated below. Those marked with an asterisk have been changed since the last report.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~33 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~11 MW
GPSS power-on threshold (p.u. MVA)	1.0	No GPSS
GPSS power-on MVA hysteresis (p.u. MVA)	0	
GPSS turn-on frequency (Hz)	0.5	
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	10	1.0 seconds
Number half cycles between logger saves	2	10 second record

On/Off Control	Setting	Comment
Autotrigger Values		
EPSS Output	0.02	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	120	1.0 seconds
Priority	2	

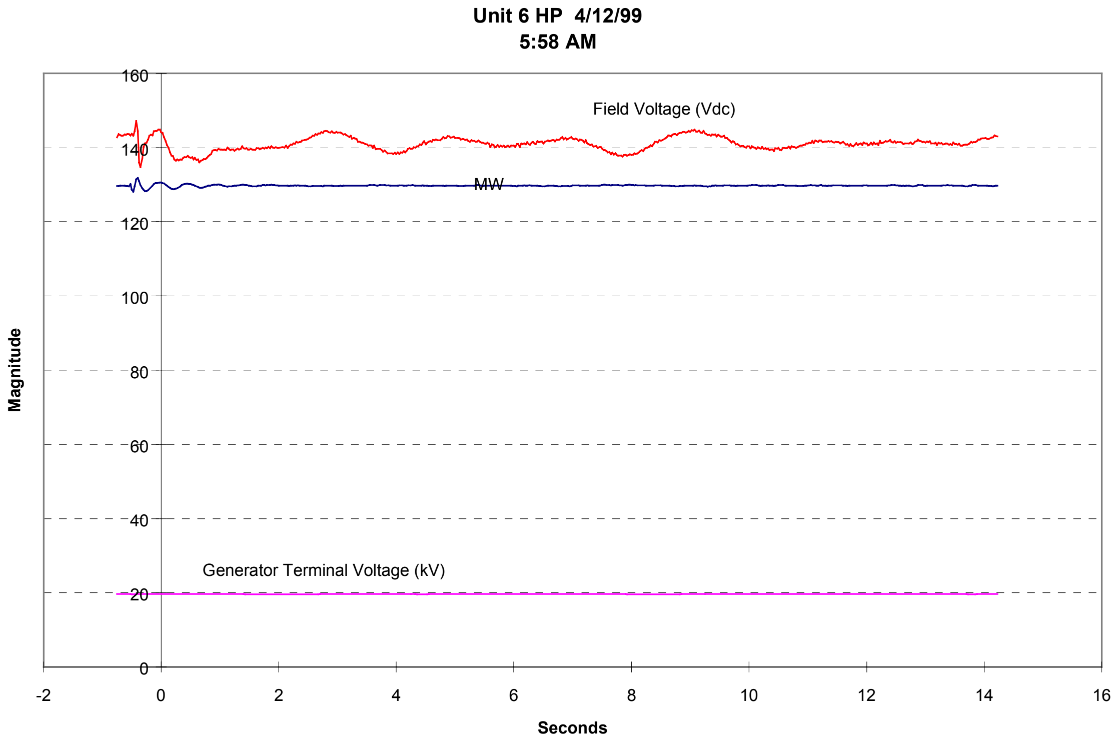
Observations

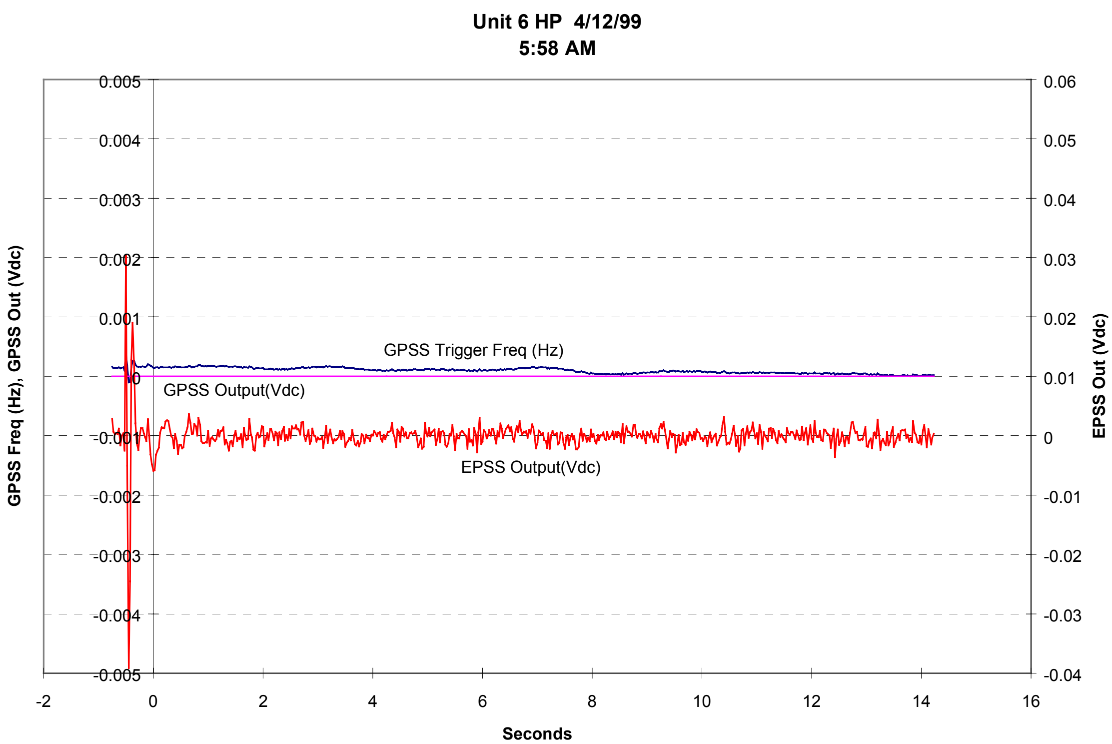
The MW load for all HP included data records during the events captured in late April and May 1999 are all above the ON enable setpoint of 0.36 p.u. or 100 MW for any GPSS operation. However, the data records indicate the GPSS trigger frequency never approached the 0.005 Hz turn on threshold. Two LP data records are included to demonstrate operation of LP EPSS.

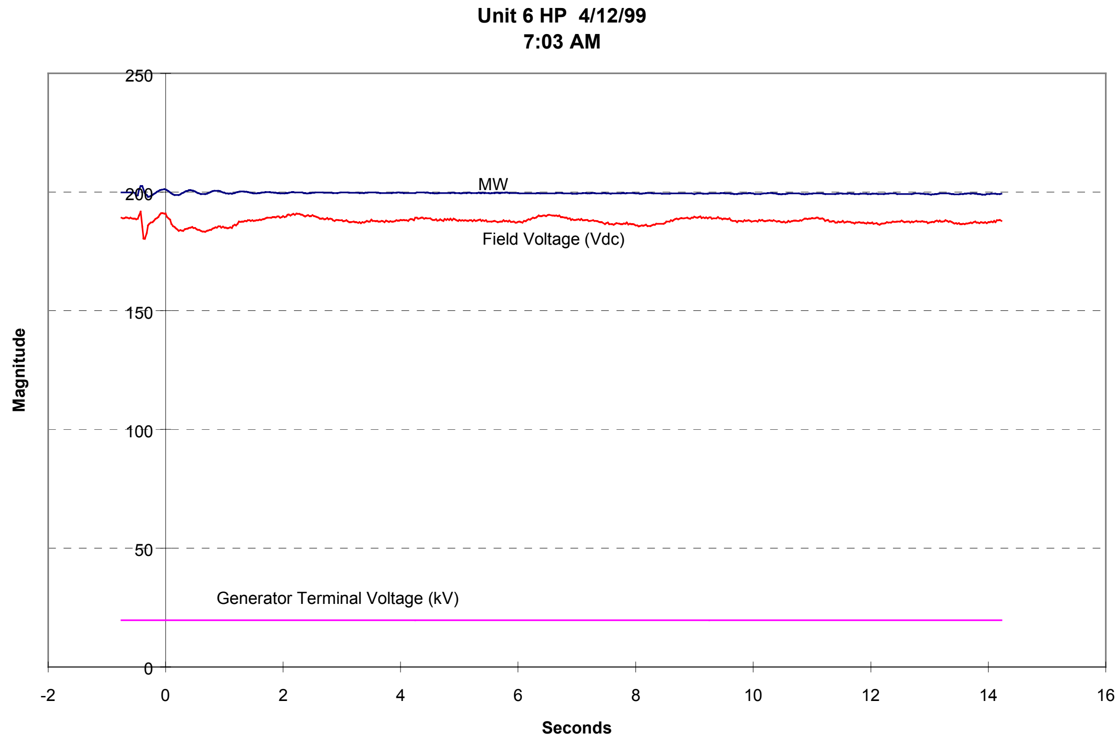
The data recorder trigger threshold for the GPSS will be reset to a lower value in incremental steps until a data record is obtained for a GPSS trigger indication. The actual GPSS trigger setpoint will remained unchanged and will operate only if the frequency excursion exceeds the 0.02 Hz threshold. The data will be evaluated prior to making any actual operational changes.

Additionally, during the commissioning of the Unit 5 IPSS, it was discovered that the GPSS will not operate correctly in SOLO mode. The mode was changed to allow DUAL operation. Future data will reflect this change in mode status.

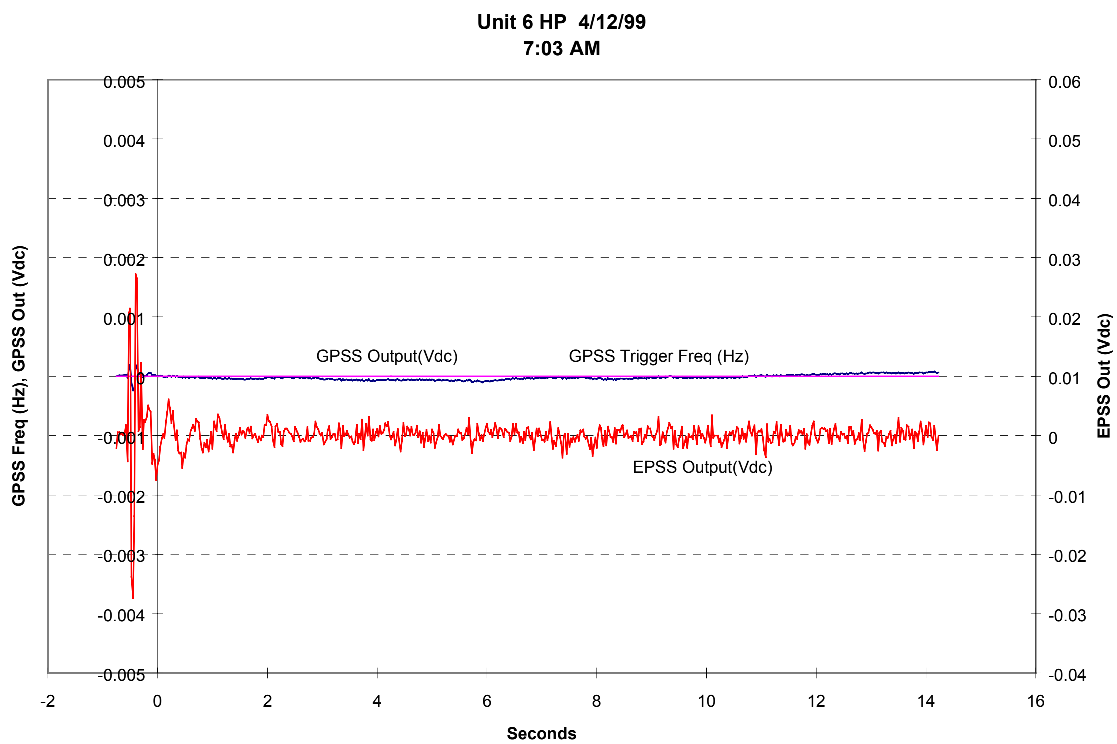
Attachments


Unit 6 HP 4/12/99
5:58 AM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
Magnitude
Seconds
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16


Unit 6 HP 4/12/99
5:58 AM
GPSS Trigger Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

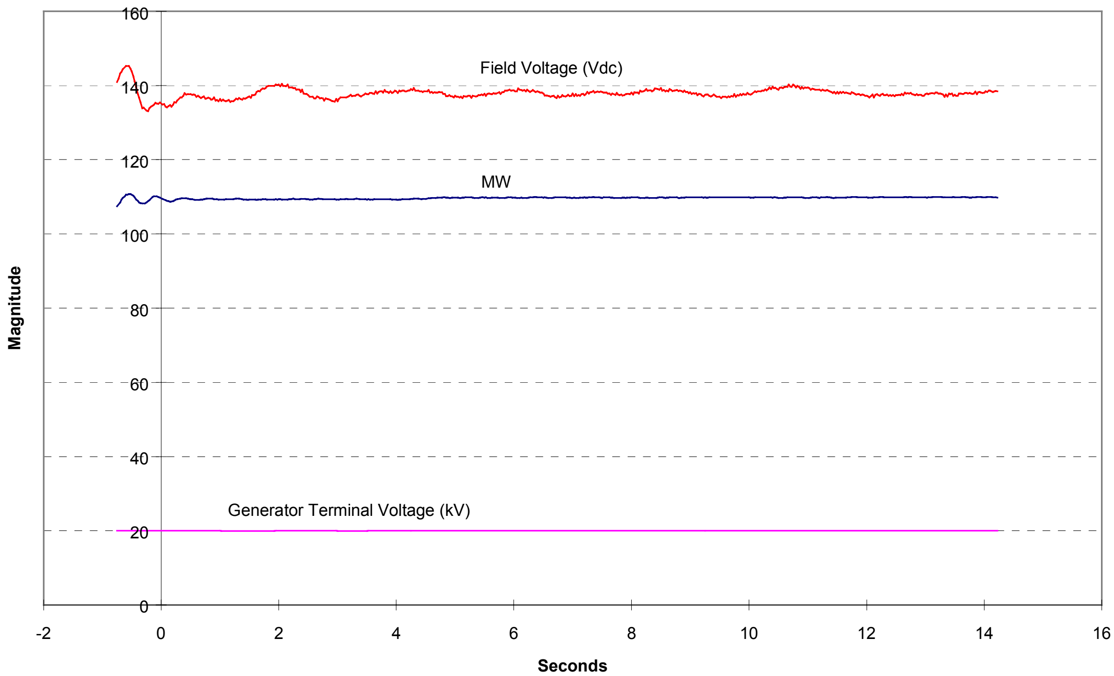


Unit 6 HP 4/12/99
7:03 AM
Magnitude
250
200
150
100
50
0
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
-2
0
2
4
6
8
10
12
14
16
Seconds

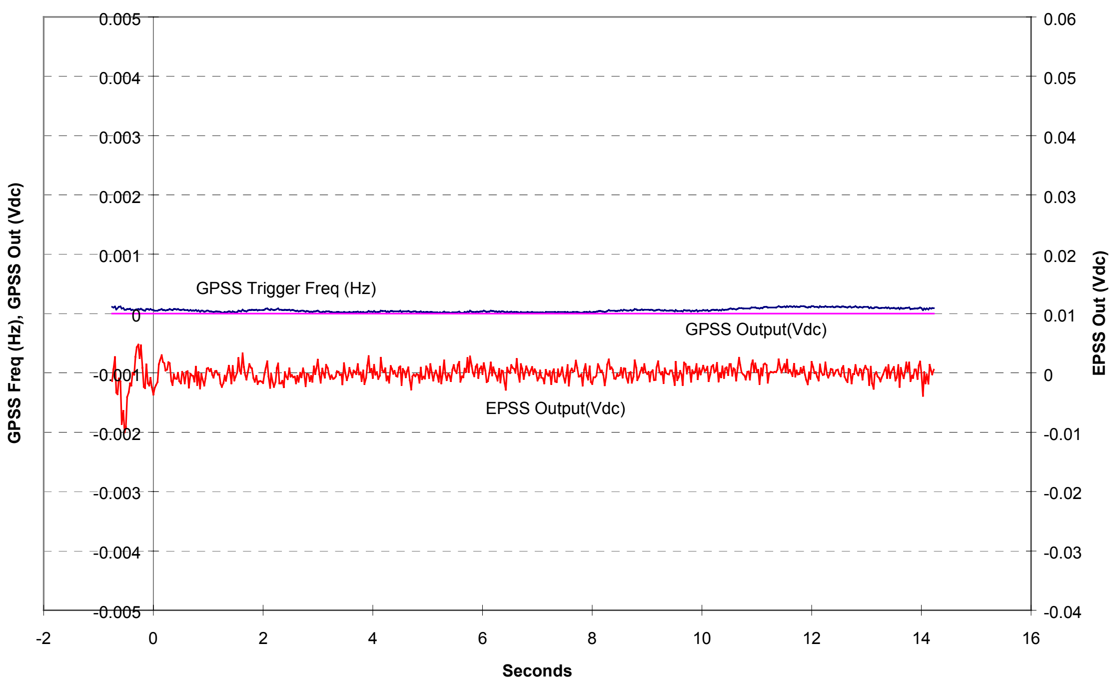


Unit 6 HP 4/12/99
7:03 AM
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
GPSS Output(Vdc)
GPSS Trigger Freq (Hz)
EPSS Output(Vdc)
-2
0
2
4
6
8
10
12
14
16
Seconds

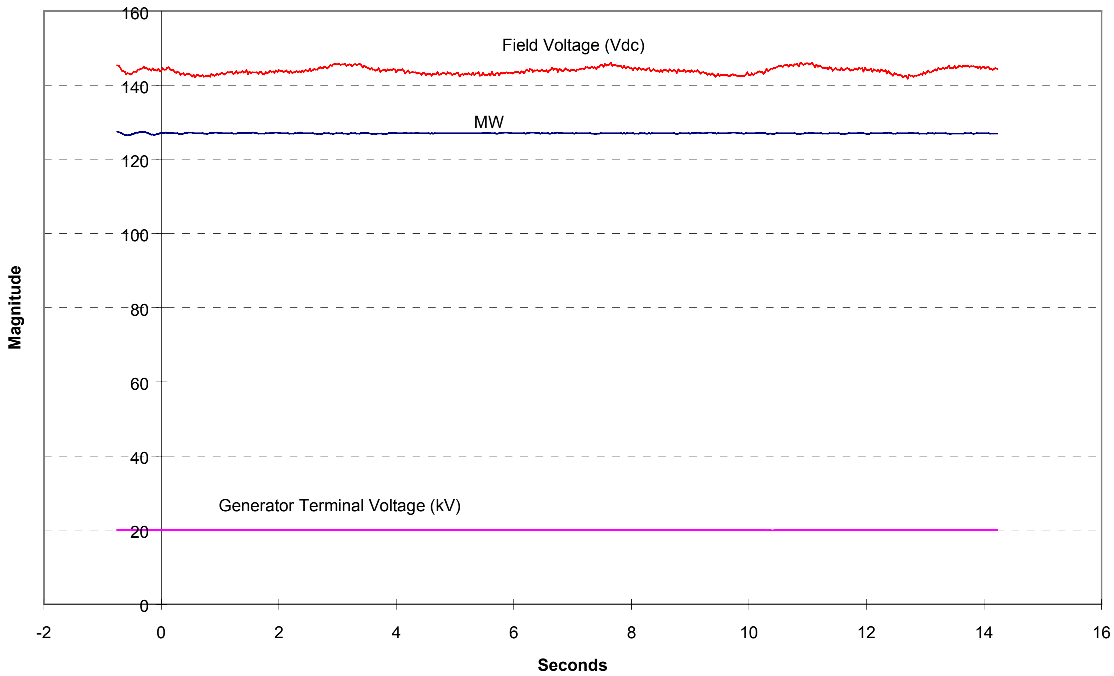
Unit 6 HP 5/3/99
5:58 PM



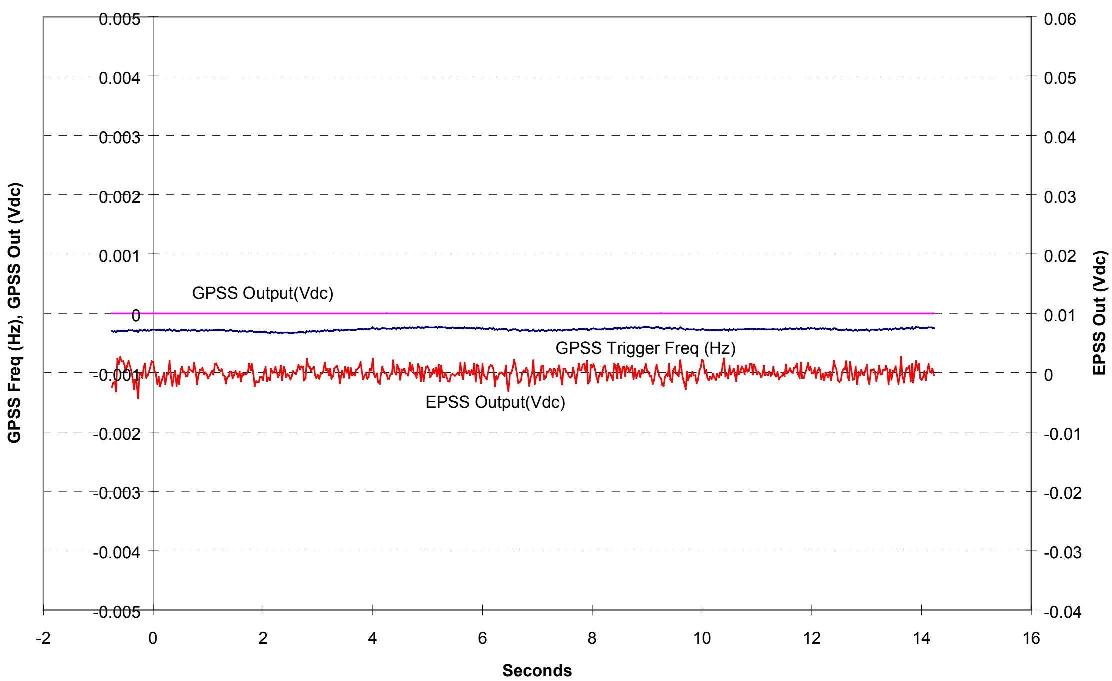
Unit 6 HP 5/3/99
5:58 PM

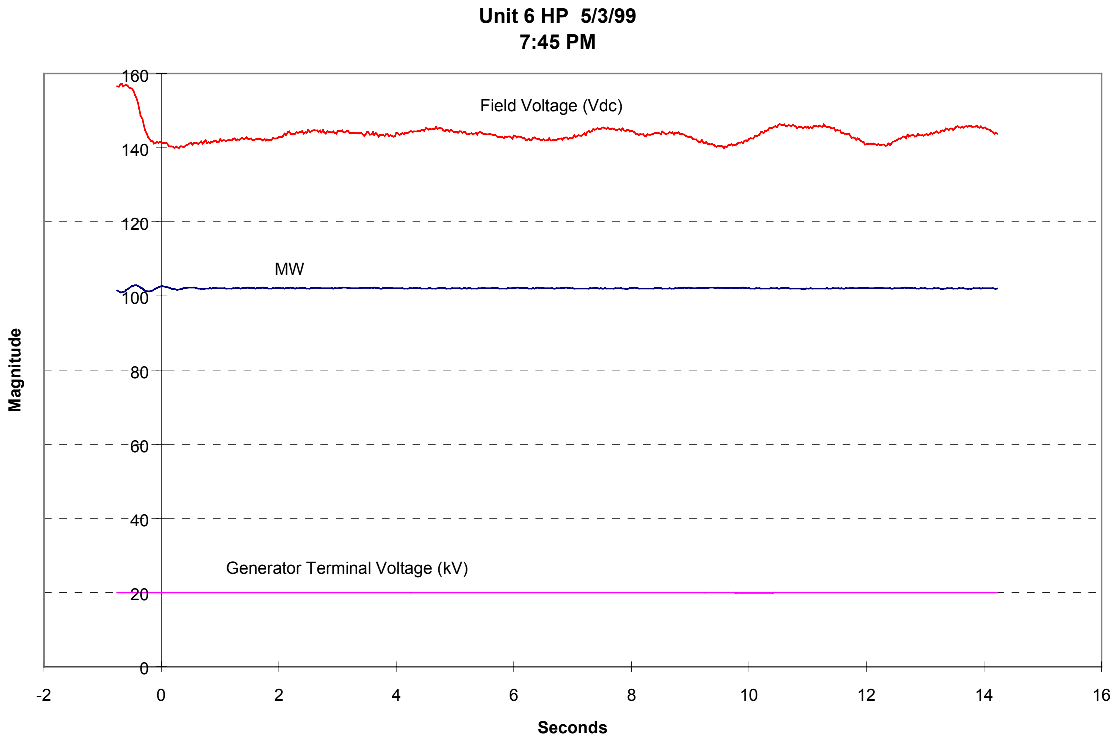


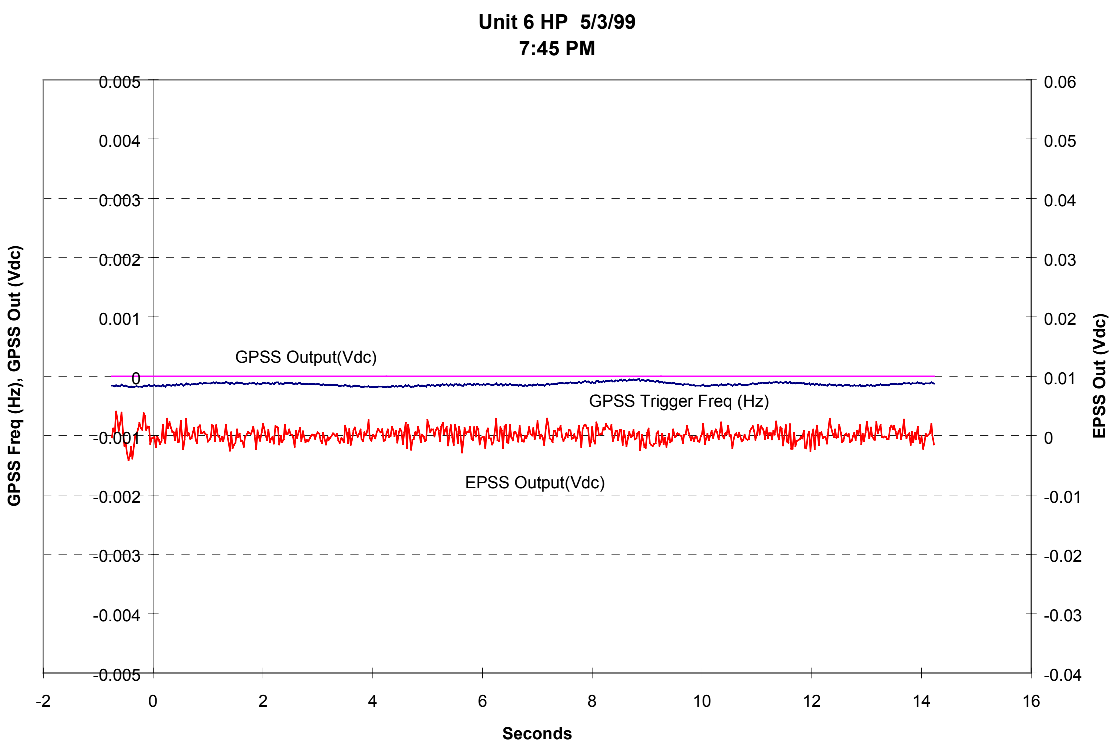
Unit 6 HP 5/3/99
6:51 PM



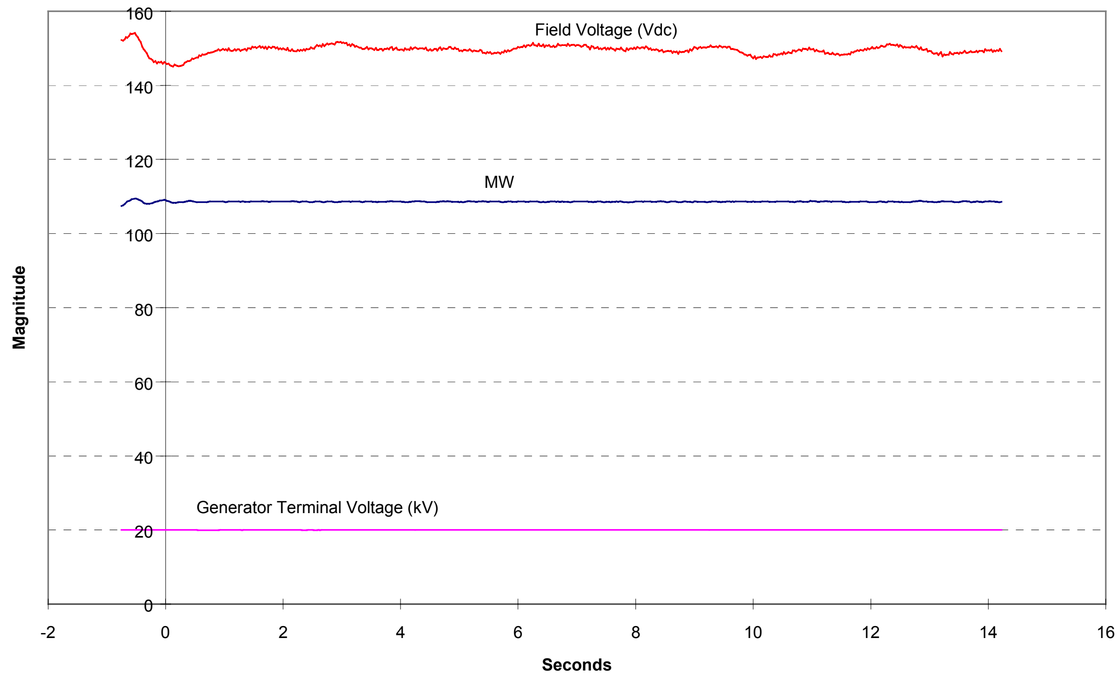
Unit 6 HP 5/3/99
6:51 PM



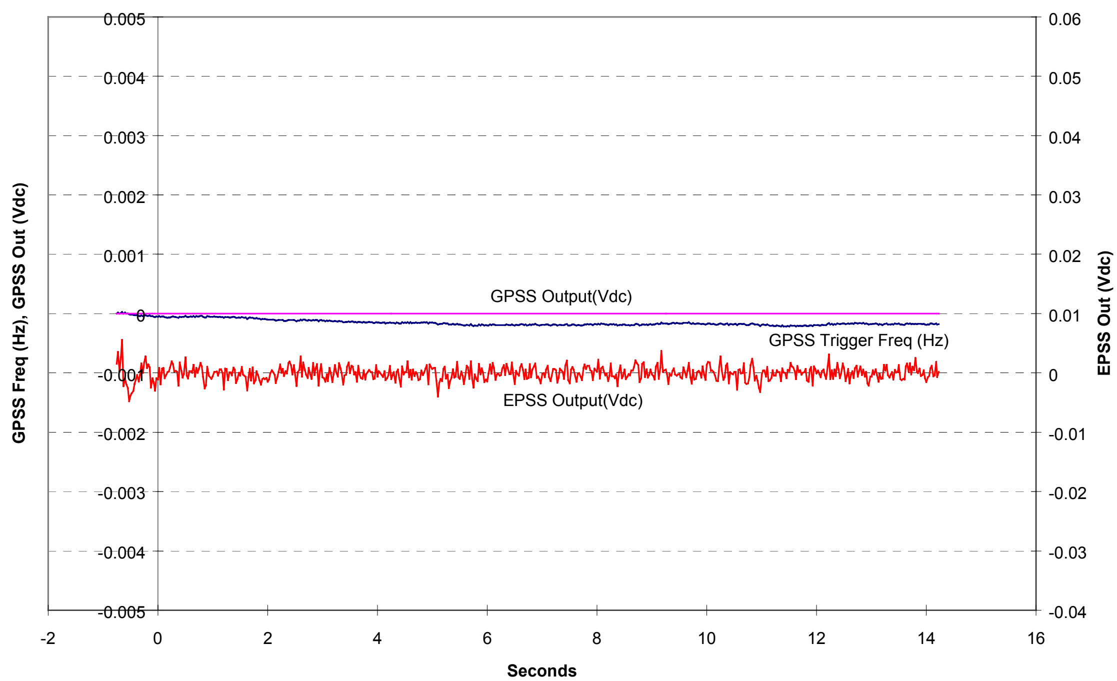

Unit 6 HP 5/3/99
7:45 PM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
Magnitude
Seconds
160
140
120
100
80
60
40
20
0
-2
0
2
4
6
8
10
12
14
16


Unit 6 HP 5/3/99
7:45 PM
GPSS Output(Vdc)
GPSS Trigger Freq (Hz)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.005
0.004
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
-0.004
-0.005
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

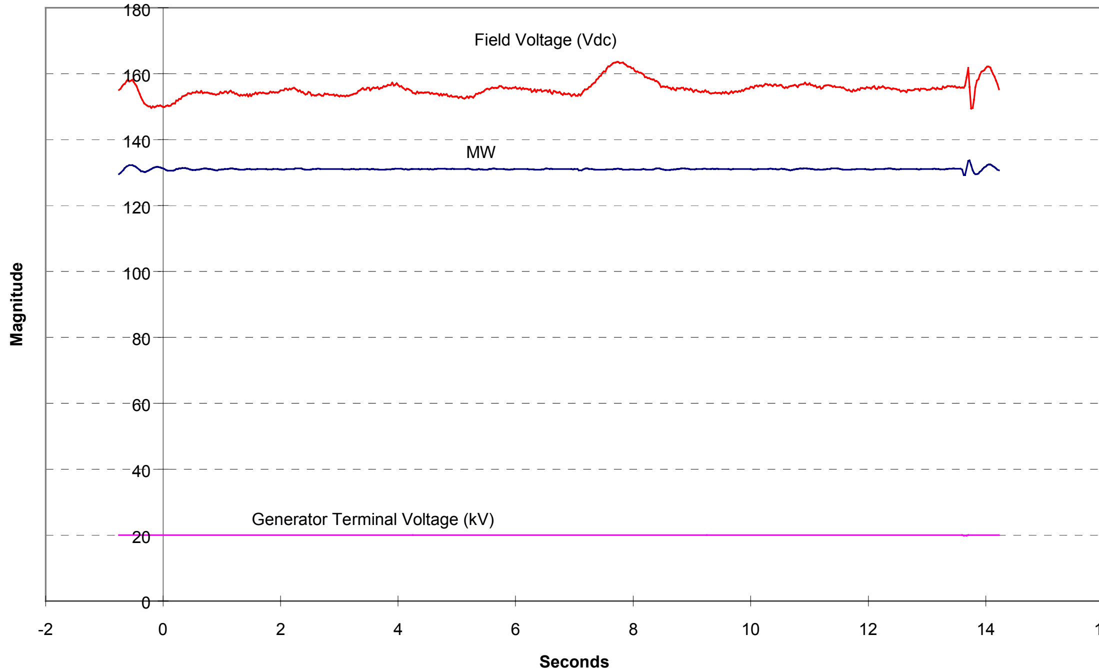
Unit 6 HP 5/3/99
7:53 PM



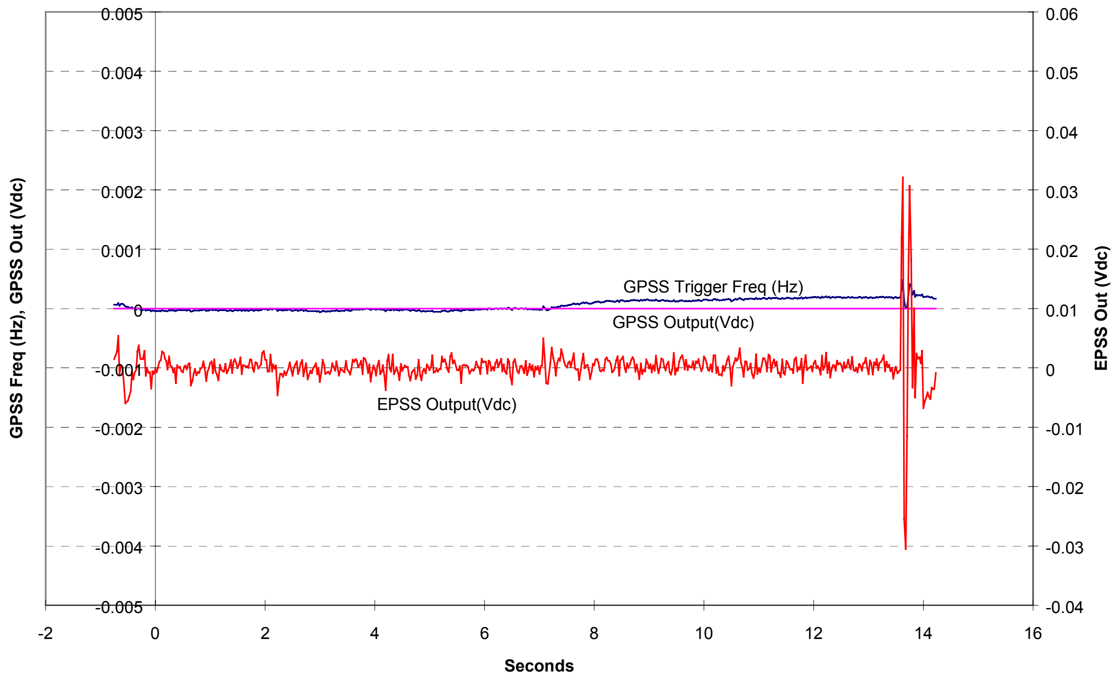
Unit 6 HP 5/3/99
7:53 PM

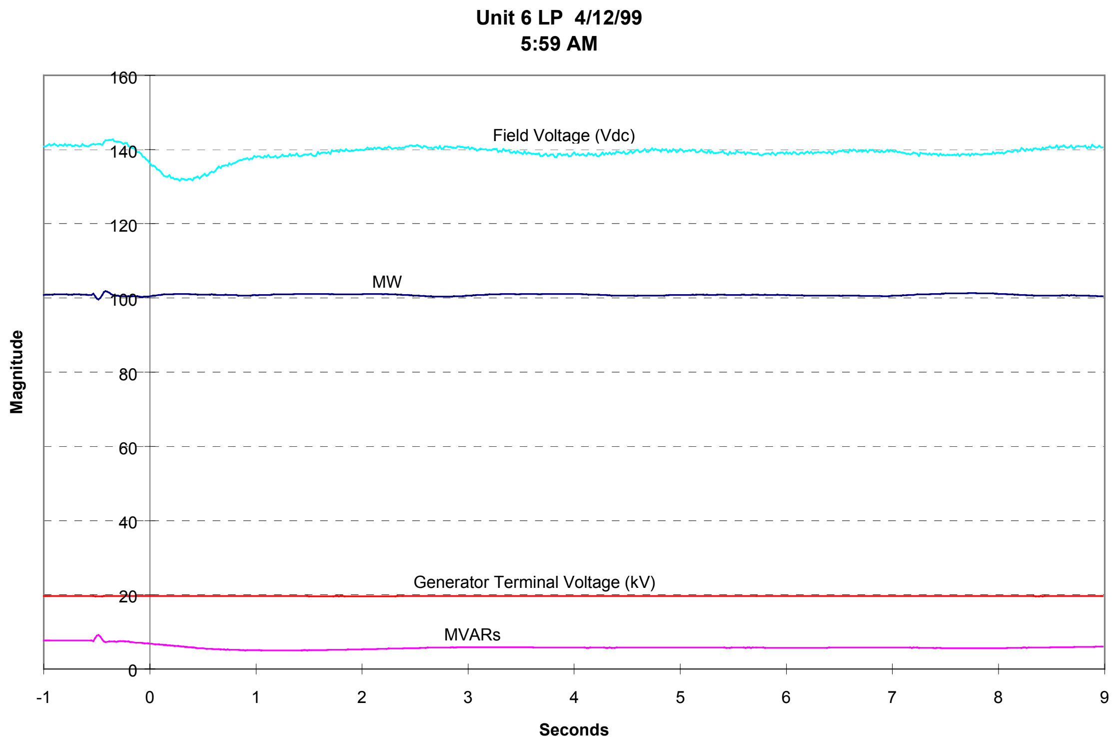


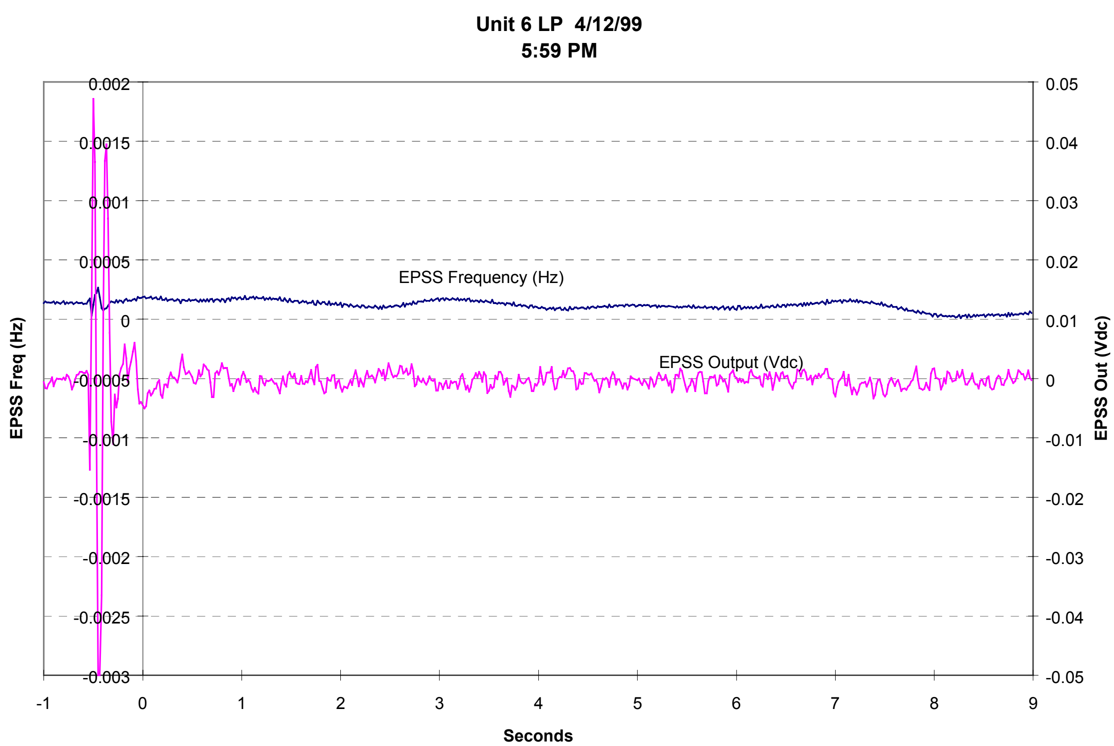
Unit 6 HP 5/3/99
9:00 PM

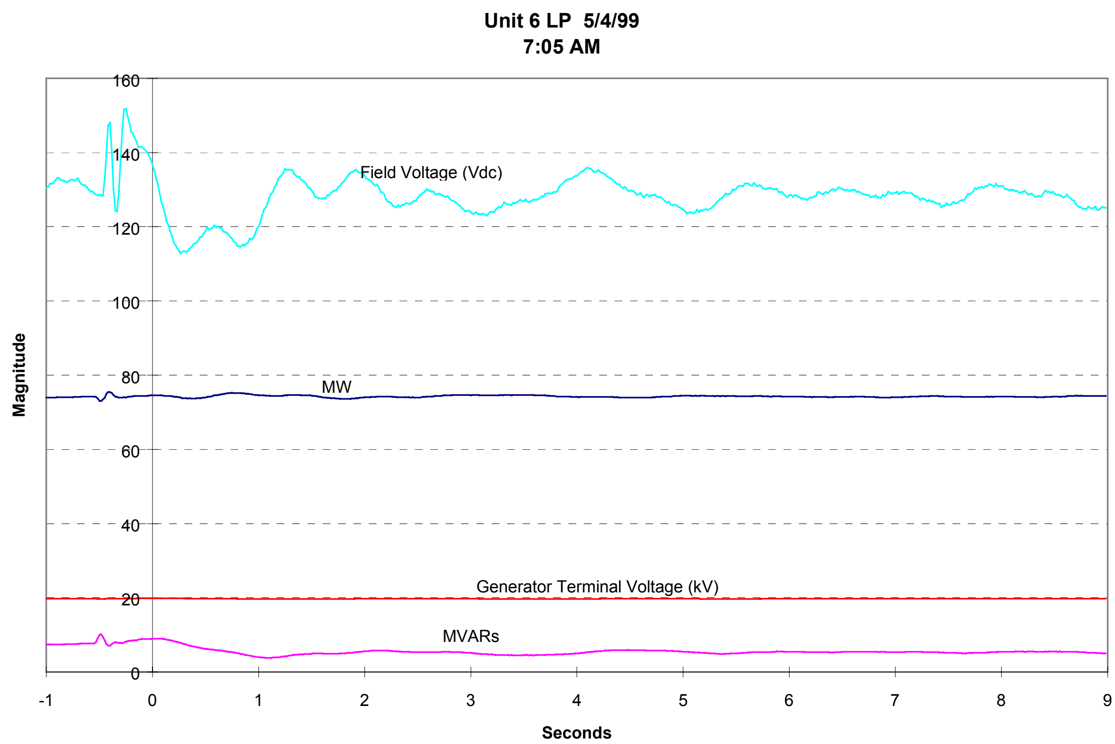


Unit 6 HP 5/3/99
9:00 PM

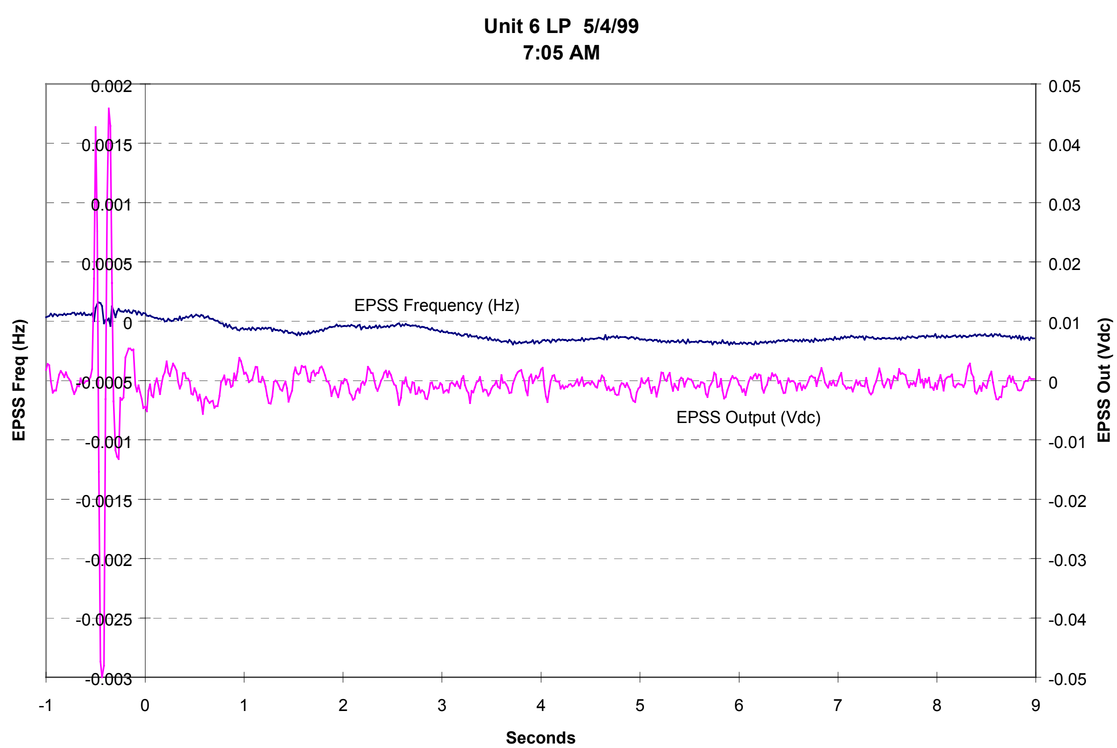



Unit 6 LP 4/12/99
5:59 AM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
MVARs
Magnitude
Seconds
160
140
120
100
80
60
40
20
0
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 4/12/99
5:59 PM
EPSS Frequency (Hz)
EPSS Output (Vdc)
EPSS Freq (Hz)
EPSS Out (Vdc)
Seconds
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
-0.0025
-0.003
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-1
0
1
2
3
4
5
6
7
8
9



Unit 6 LP 5/4/99
7:05 AM
Magnitude
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
MVARs
Seconds



Unit 6 LP 5/4/99
7:05 AM
EPSS Freq (Hz)
EPSS Out (Vdc)
EPSS Frequency (Hz)
EPSS Output (Vdc)
Seconds

Appendix X
Data Collected for Units 5 and 6 After 5/4/99

Unit: 5 and 6
Date of Work: 5/4/99 - 8/18/99

Brief Description of Work Performed

ESI engineering personnel downloaded data on 6/24/99, 8/6/99, and 8/18/99 to collect the data records for the previous months operation. Charts of selected data are included in the attachments to this report. The electrical power system stabilizer (EPSS) portion of the IPSS for both the Unit 5 and Unit 6 HP and LP generators have triggered several data records. The governor power system stabilizer (GPSS) portion of the IPSS on both the Unit 5 and Unit 6 HP generators also triggered a few data records.

The captured data records of the operation of the GPSS provide positive feedback on the design of the IPSS and its ability to affect MW changes on the generator. The present GPSS gain provided some damping of the MW oscillations but needs to be increased towards the final value identified in the initial studies.

The charts include the MW load, the generator terminal voltage, the field voltage, GPSS compensated frequency signal, GPSS output, EPSS sensing frequency, and EPSS output where applicable.

HP GPSS and EPSS Settings

The operating parameters for the GPSS and EPSS as well as the data recorder settings for the Unit 5 and 6 HP generators are tabulated below. Those marked with an asterisk have been changed since the last report.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~42 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS power-on threshold (p.u. MVA)	0.36	~100 MW
GPSS power-on MVA hysteresis (p.u. MVA)	0.05	~14 MW
GPSS turn-on frequency (Hz)	0.02	
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	5	0.75 seconds
Number half cycles between logger saves	3	15 second record
Autotrigger Values		
p.u. GPSS Trigger setpoint (Hz)	0.005	U5 = 0.02
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	20	U5 = 5
Priority	3	
EPSS Output	0.02	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	120	U5 = 60
Priority	2	

LP EPSS Settings

The operating parameters for the EPSS as well as the data recorder settings for the LP generator are tabulated below. Those marked with an asterisk have been changed since the last report.

On/Off Control	Setting	Comment
EPSS power-on threshold (p.u. MVA)	0.15	~33 MW
EPSS power-on MVA hysteresis (p.u. MVA)	0.05	~11 MW
GPSS power-on threshold (p.u. MVA)	1.0	No GPSS
GPSS power-on MVA hysteresis (p.u. MVA)	0	
GPSS turn-on frequency (Hz)	0.5	

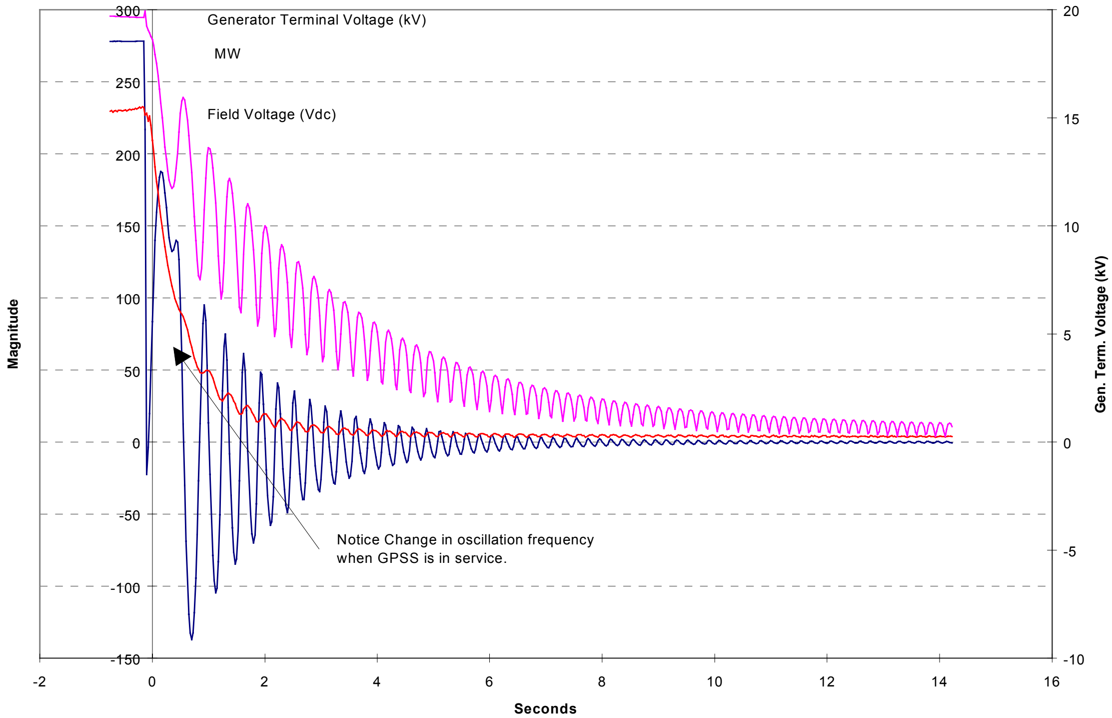
On/Off Control	Setting	Comment
GPSS turn-on hysteresis (%)	25	
Select Recorder Settings		
Percentage pre-trigger data in record	10	1.0 seconds
Number half cycles between logger saves	2	10 second record
Autotrigger Values		
EPSS Output	0.02	
LOGIC: 0=equal set point, 1=above, 2=below	1	
TYPE: 0=one shot, 1=retriggerable	1	
Number half cycle to DELAY	60	U5 = 5
Priority	2	

Observations

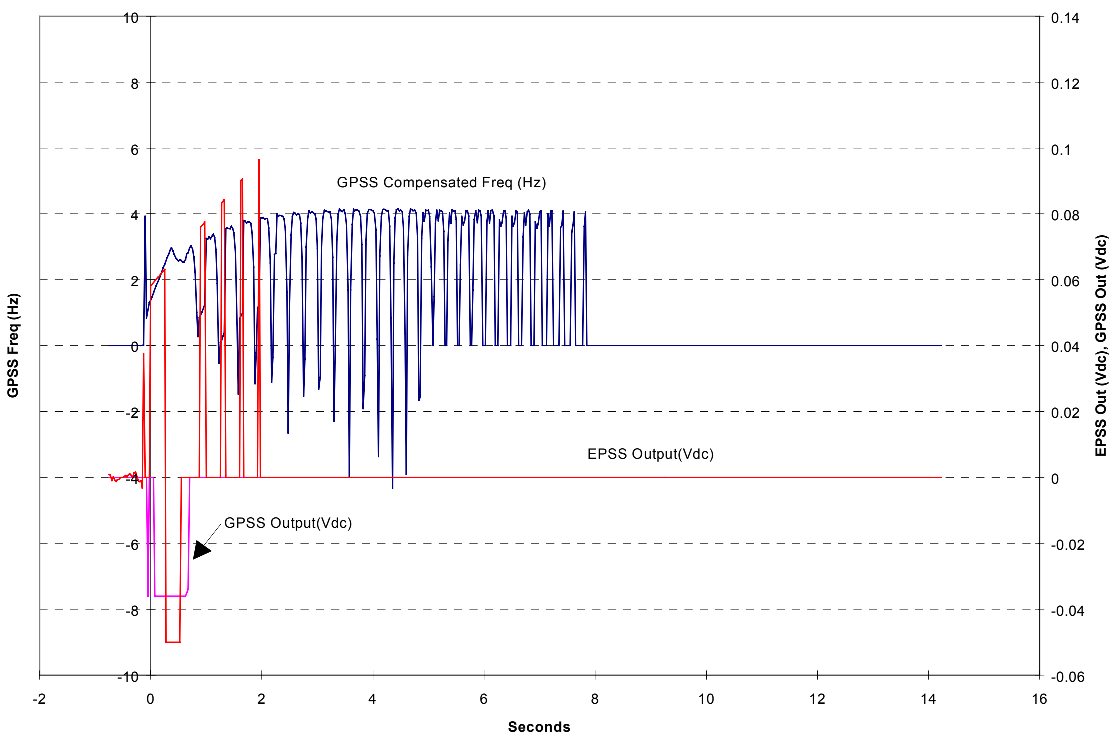
The MW load for all HP included data records during the events captured in late April and May 1999 are all above the ON enable setpoint of 0.36 p.u. or 100 MW for any GPSS operation. On 6/30/99, Unit 5 relayed from full load (480 MW) and the GPSS went in service. Unfortunately, no corresponding data record was captured on Unit 6. On 8/5/99, Unit 6 HP experienced two separate GPSS operations. Copies of these data records are included in the attached charts. Two LP data records are included to demonstrate operation of LP EPSS on Units 5 and 6.

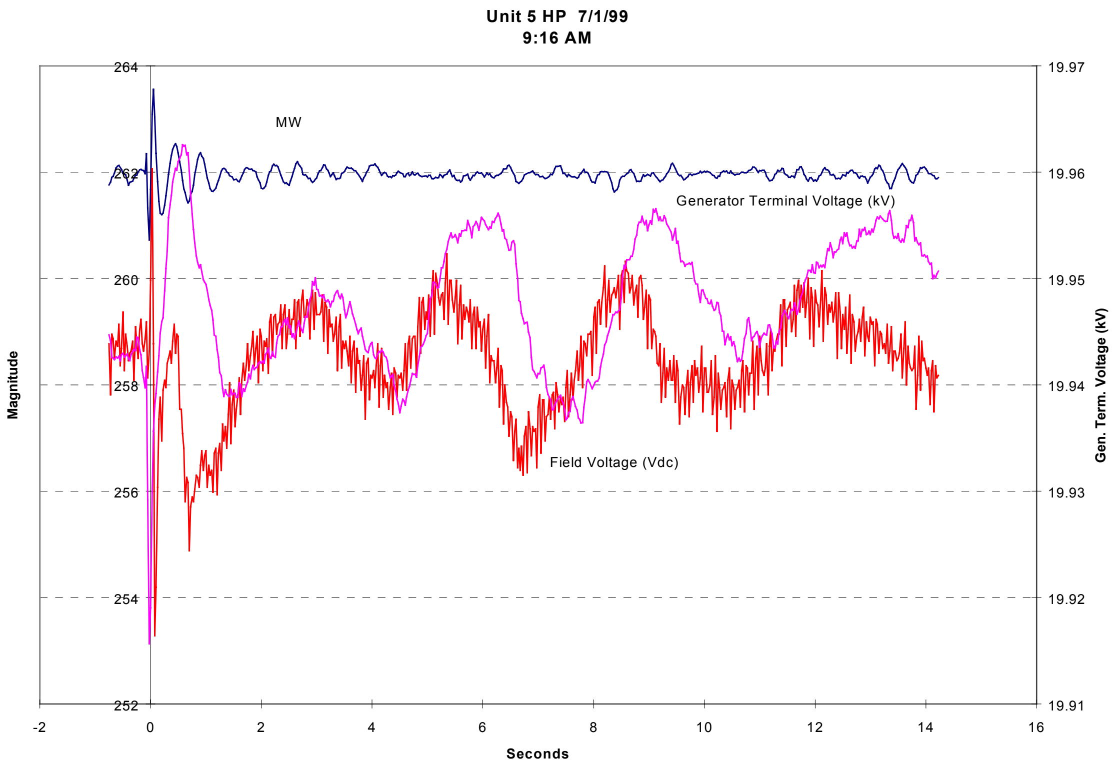
GPSS data records are generally given a Priority level 3 (highest) to avoid being overwritten by lower priority signals. In each of the GPSS data records captured by the data logger, the Priority level was recorded as a level 2 or EPSS generated record. We did have the EPSS operate during these events also. The manufacturer of the IPSS is being consulted regarding this matter. It may be necessary to change the trigger levels of the EPSS to ensure GPSS events are recorded at the appropriate priority level.

Unit 5 HP 6/30/99
5:30 PM

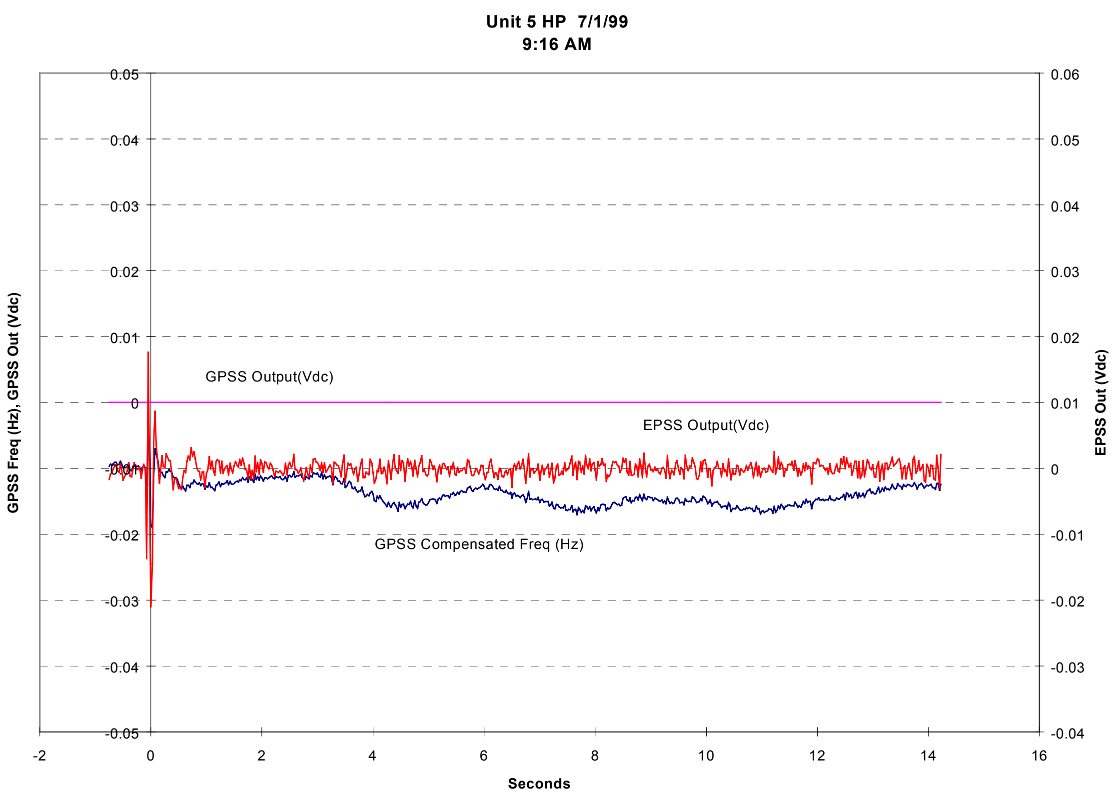


Unit 5 HP 6/30/99
5:30 PM



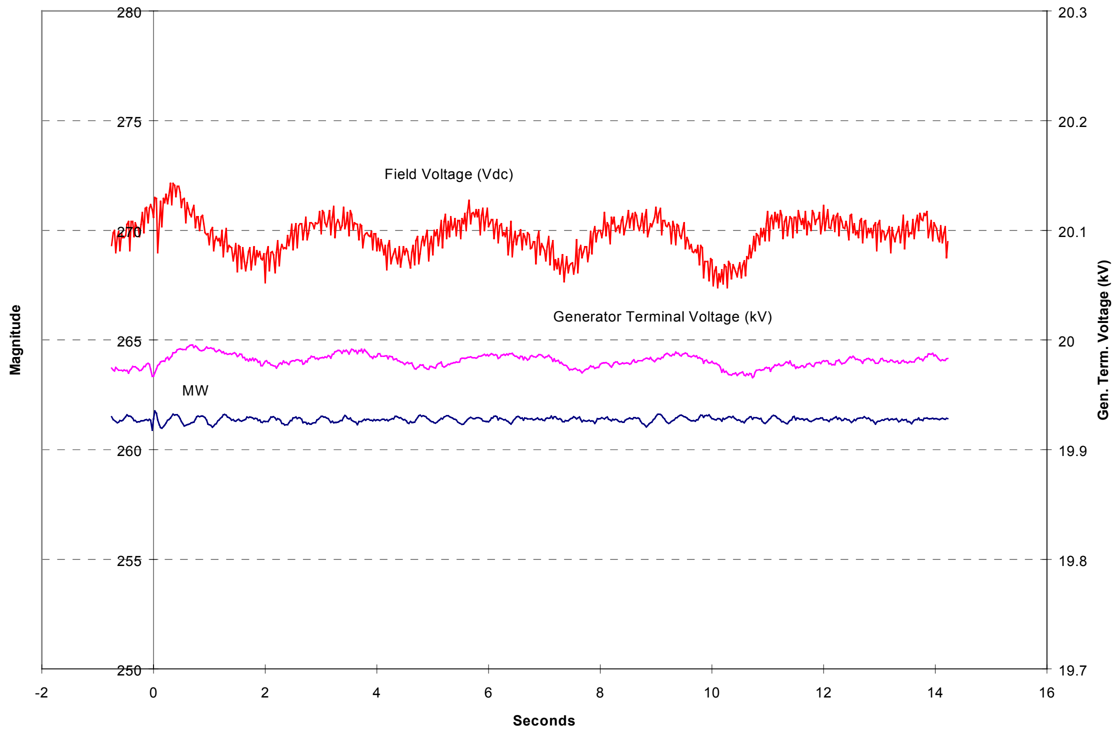


Unit 5 HP 7/1/99
9:16 AM
MW
Generator Terminal Voltage (kV)
Field Voltage (Vdc)
Magnitude
Gen. Term. Voltage (kV)
Seconds
264
262
260
258
256
254
252
19.97
19.96
19.95
19.94
19.93
19.92
19.91
-2
0
2
4
6
8
10
12
14
16

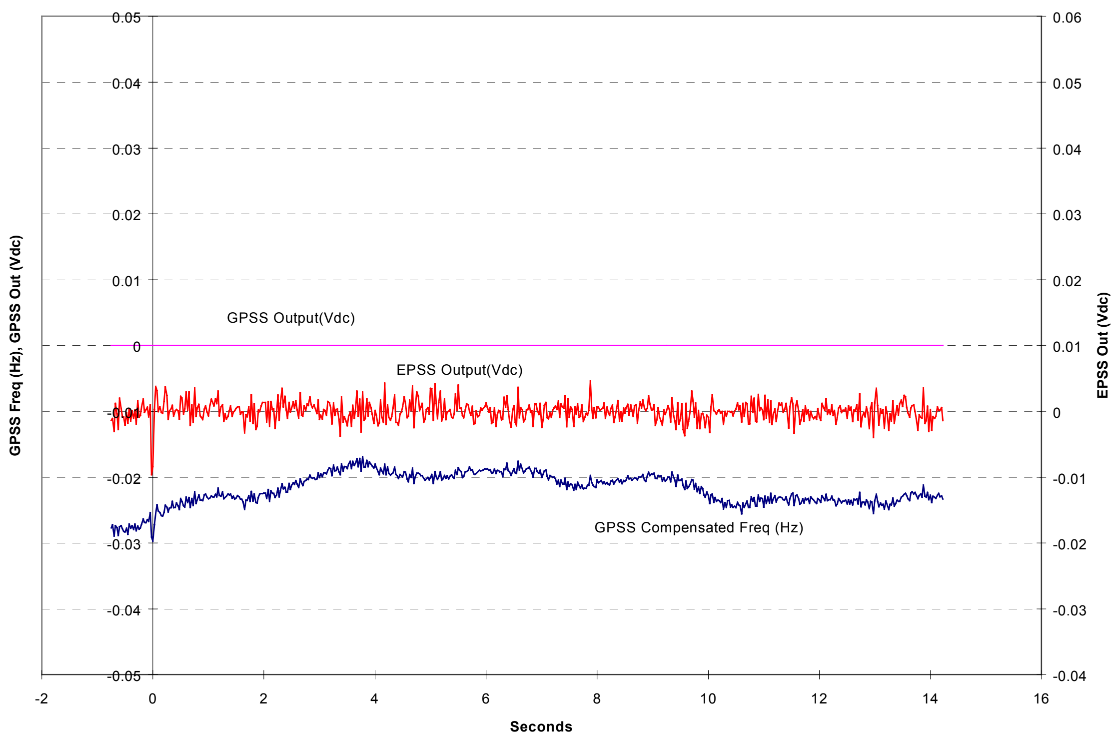


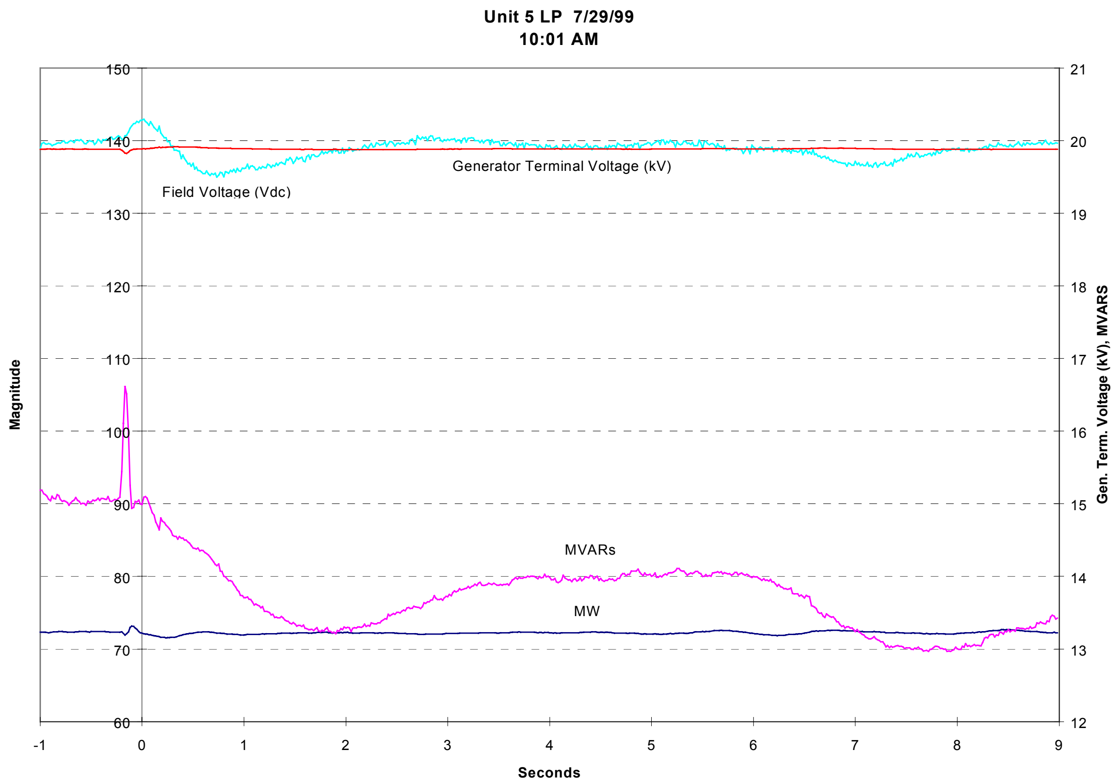
Unit 5 HP 7/1/99
9:16 AM
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Compensated Freq (Hz)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

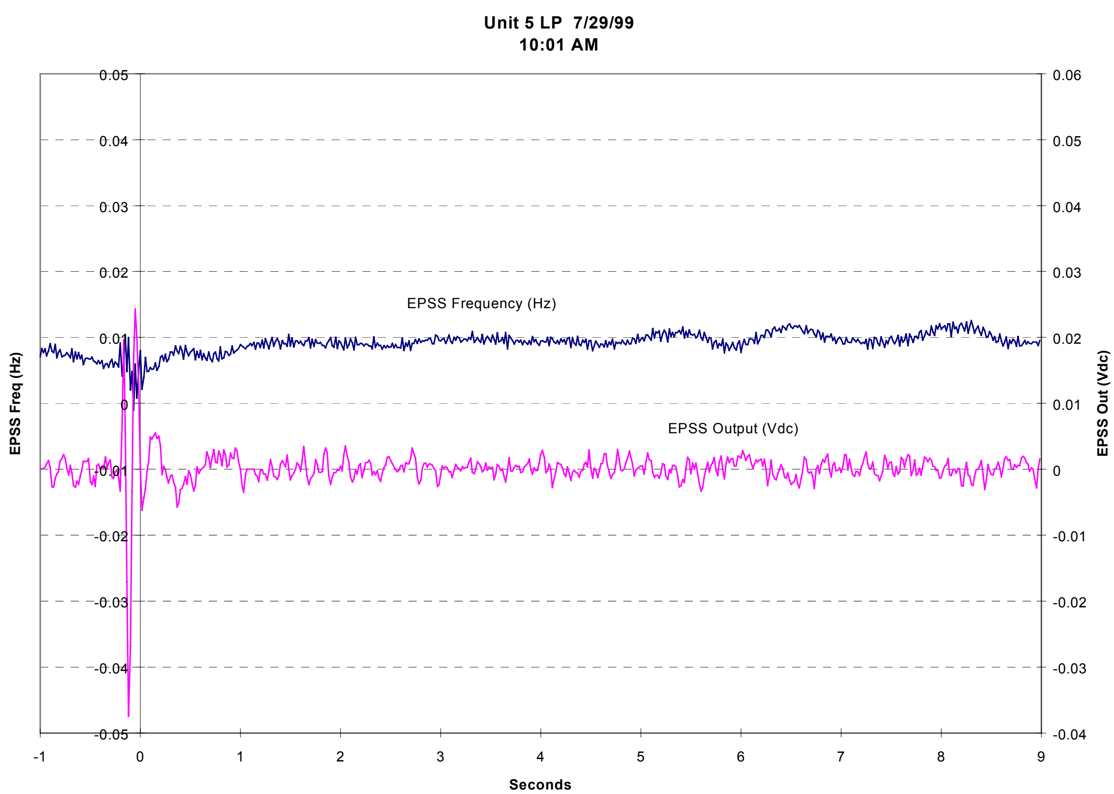
Unit 5 HP 7/1/99
11:24 AM



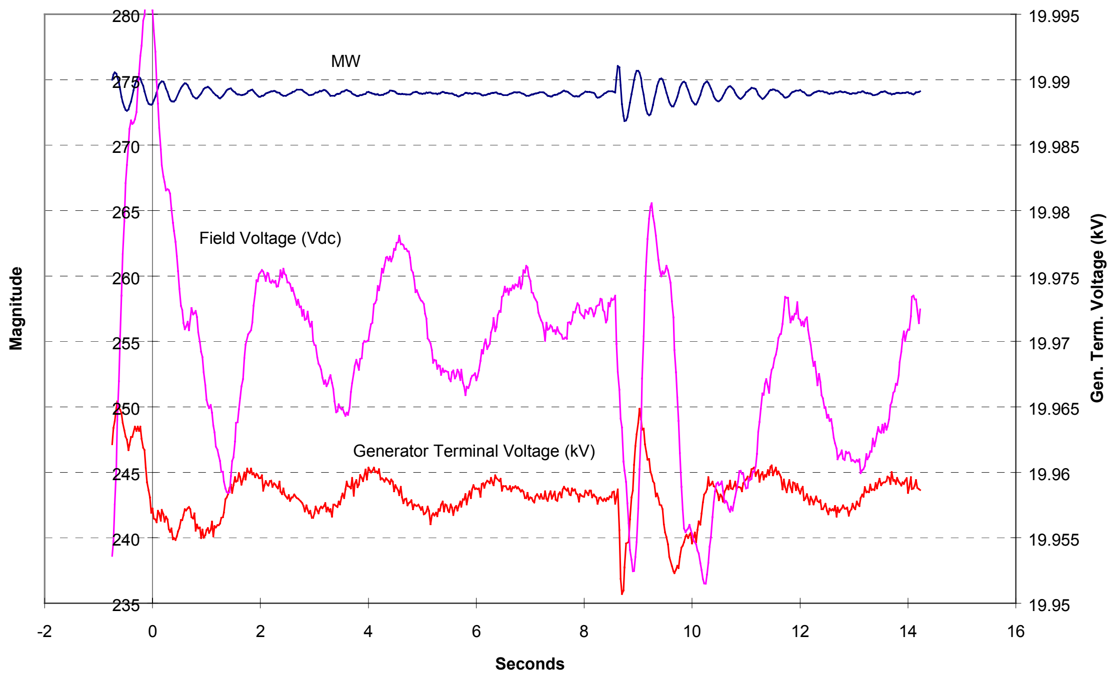
Unit 5 HP 7/1/99
11:24 AM



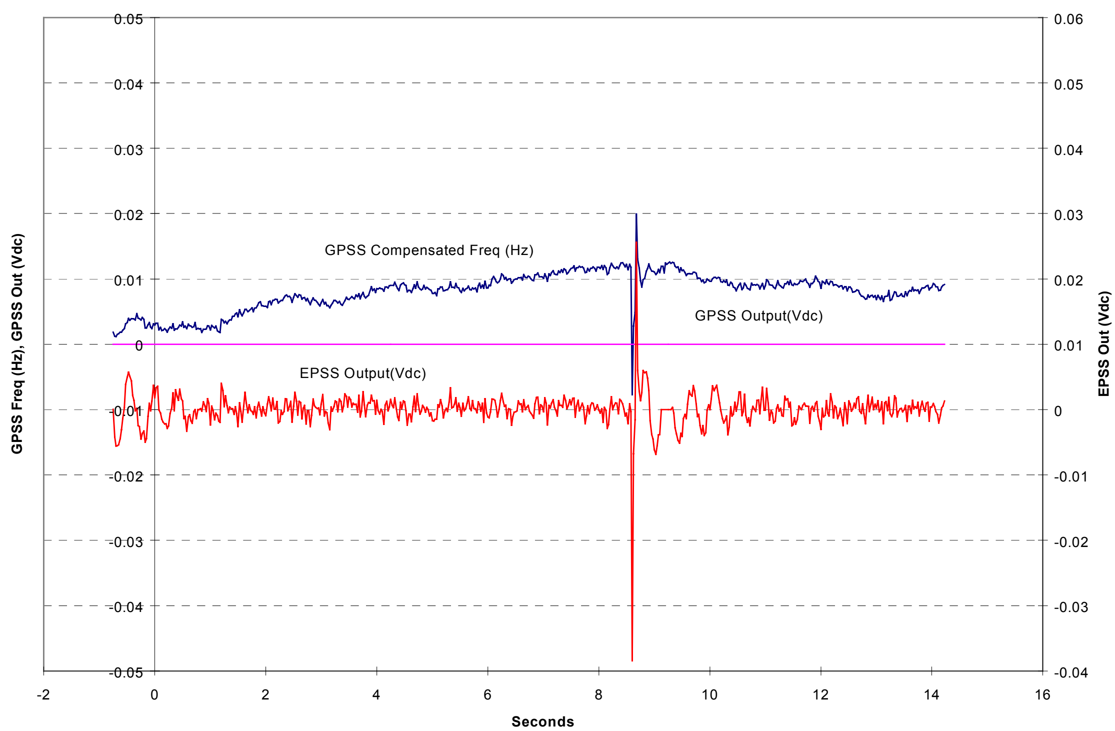

Unit 5 LP 7/29/99
10:01 AM
Generator Terminal Voltage (kV)
Field Voltage (Vdc)
MVARs
MW
Magnitude
Gen. Term. Voltage (kV), MVARS
Seconds
150
140
130
120
110
100
90
80
70
60
21
20
19
18
17
16
15
14
13
12
-1
0
1
2
3
4
5
6
7
8
9

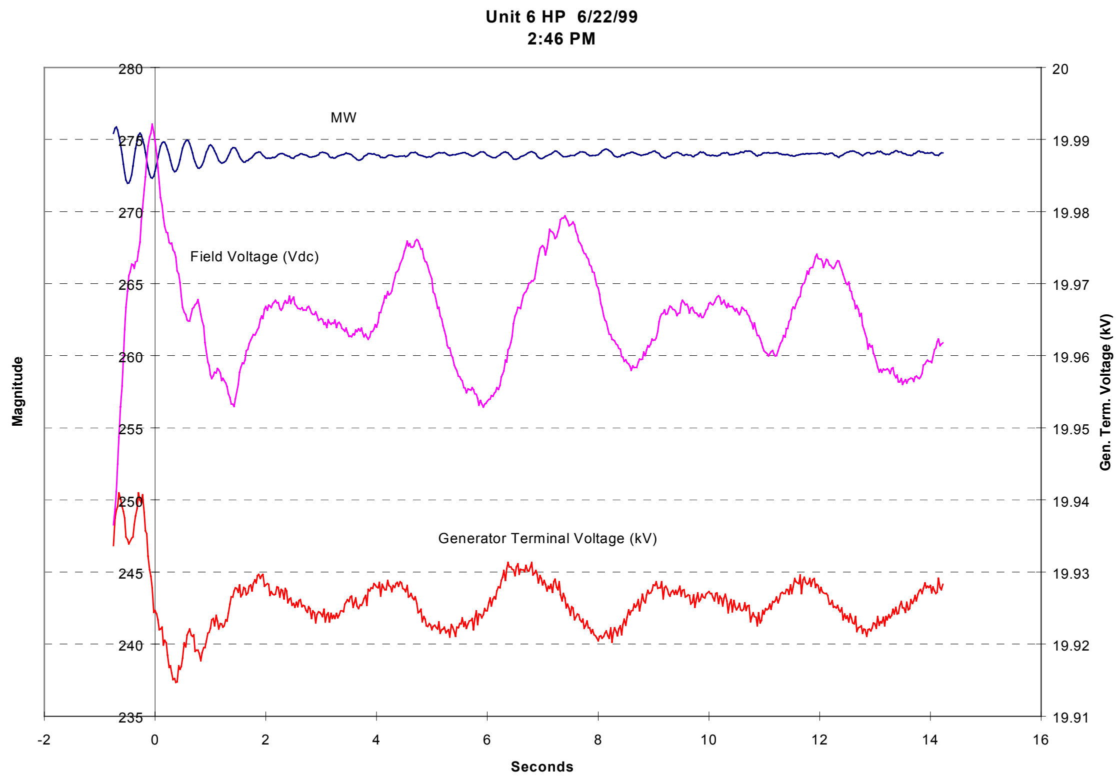

Unit 5 LP 7/29/99
10:01 AM
EPSS Frequency (Hz)
EPSS Output (Vdc)
EPSS Freq (Hz)
EPSS Out (Vdc)
Seconds
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-1
0
1
2
3
4
5
6
7
8
9

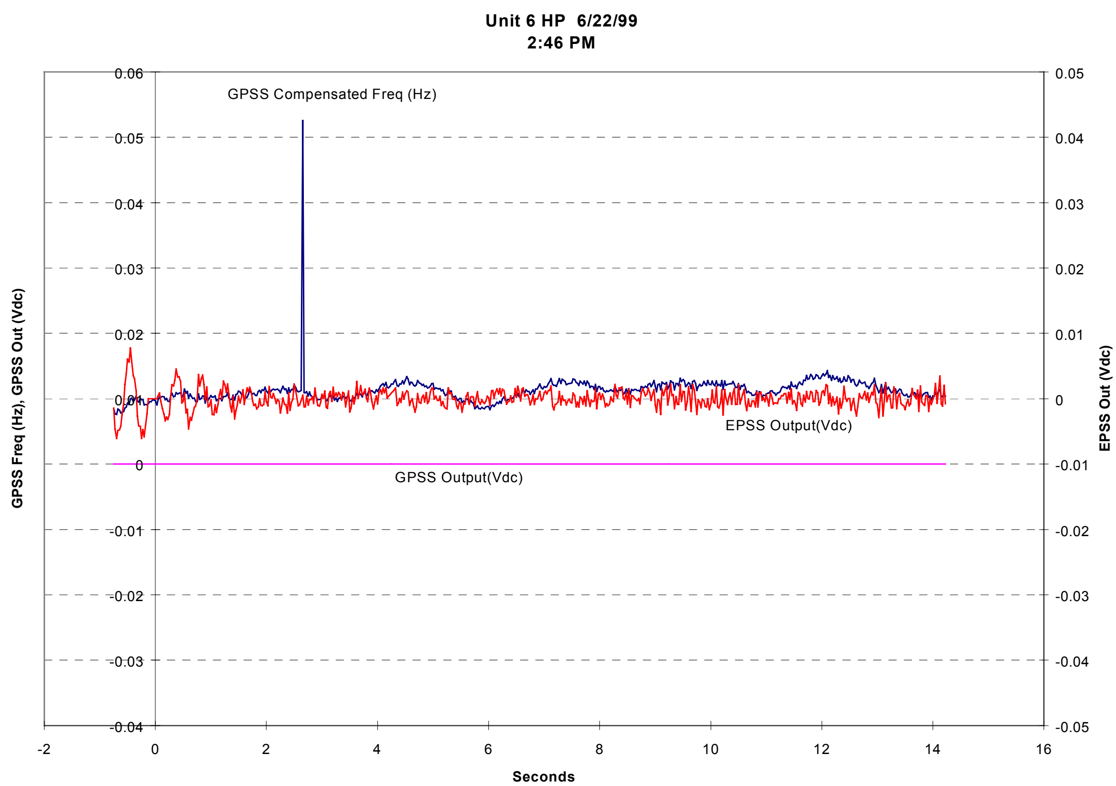
Unit 6 HP 6/22/99
2:45 PM



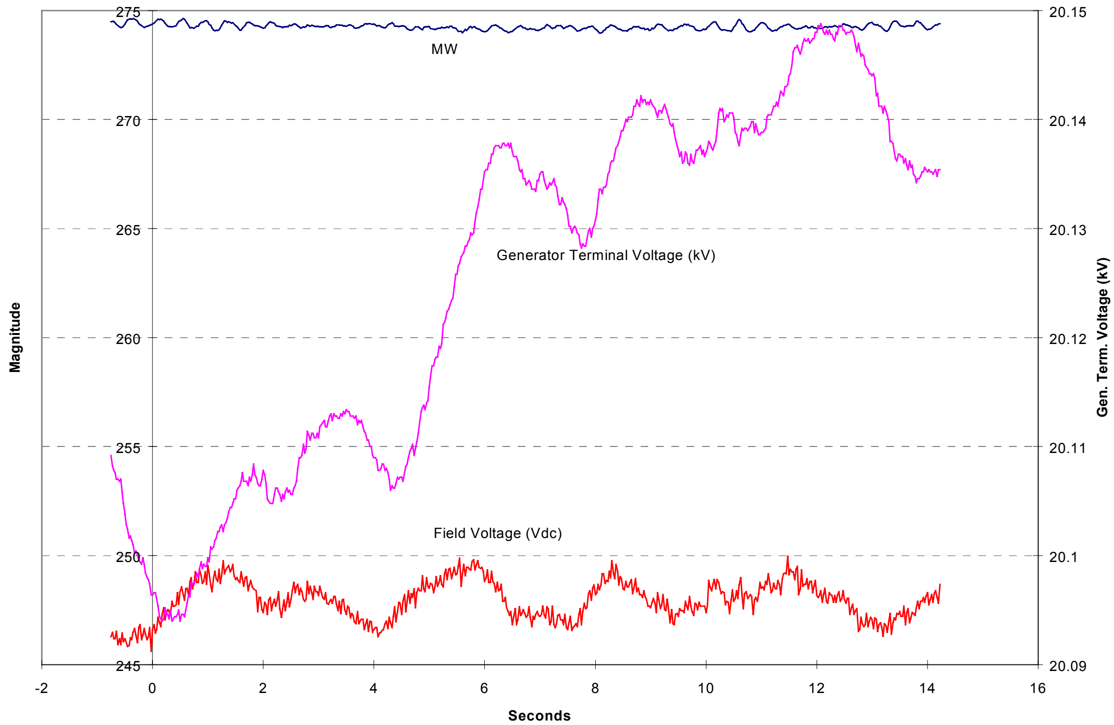
Unit 6 HP 6/22/99
2:45 PM



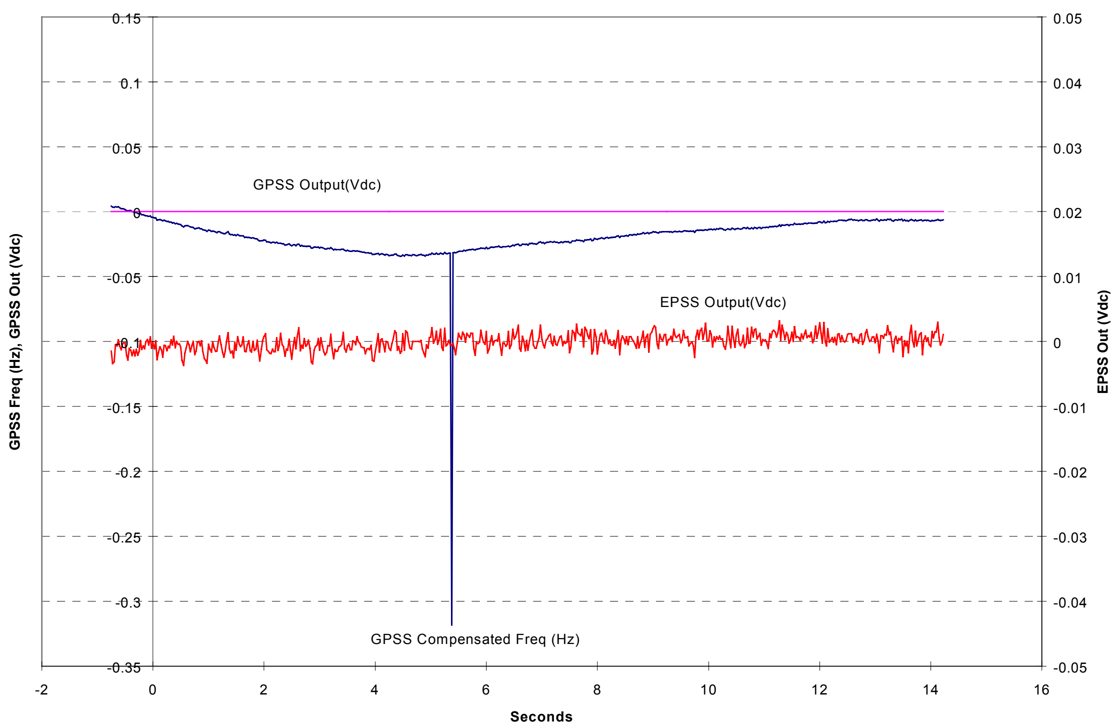

Unit 6 HP 6/22/99
2:46 PM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Gen. Term. Voltage (kV)
Seconds

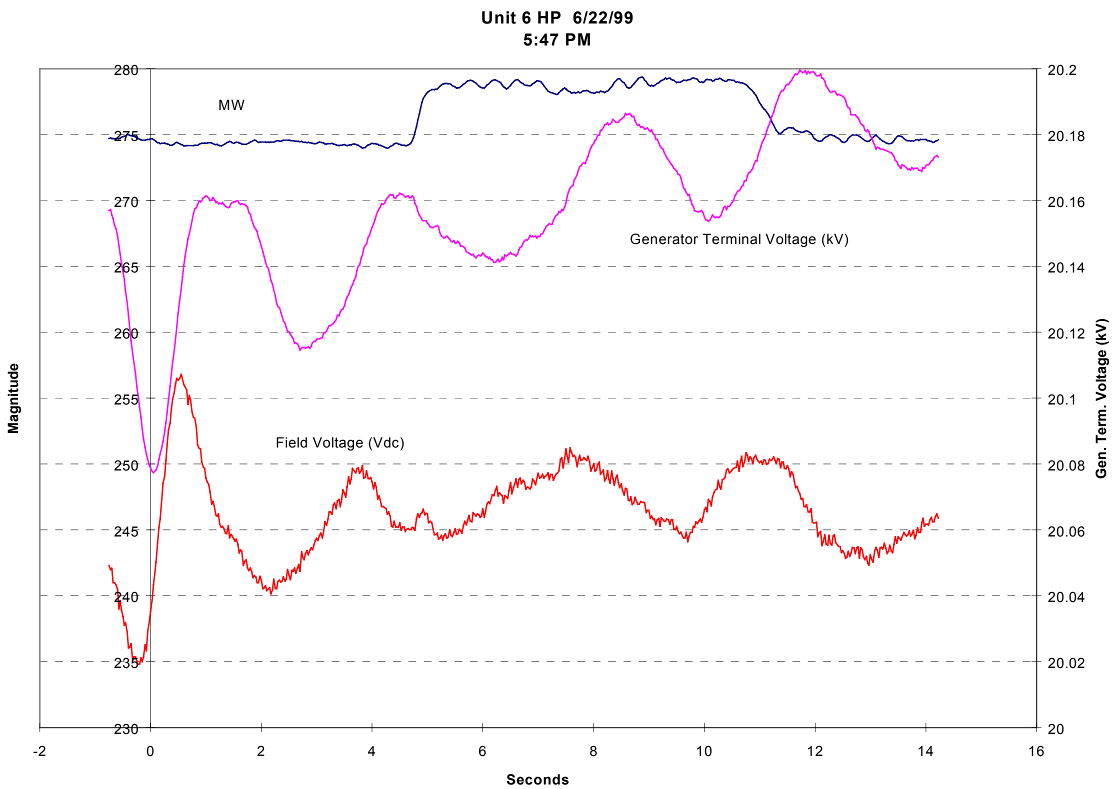

Unit 6 HP 6/22/99
2:46 PM
GPSS Compensated Freq (Hz)
EPSS Output(Vdc)
GPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds

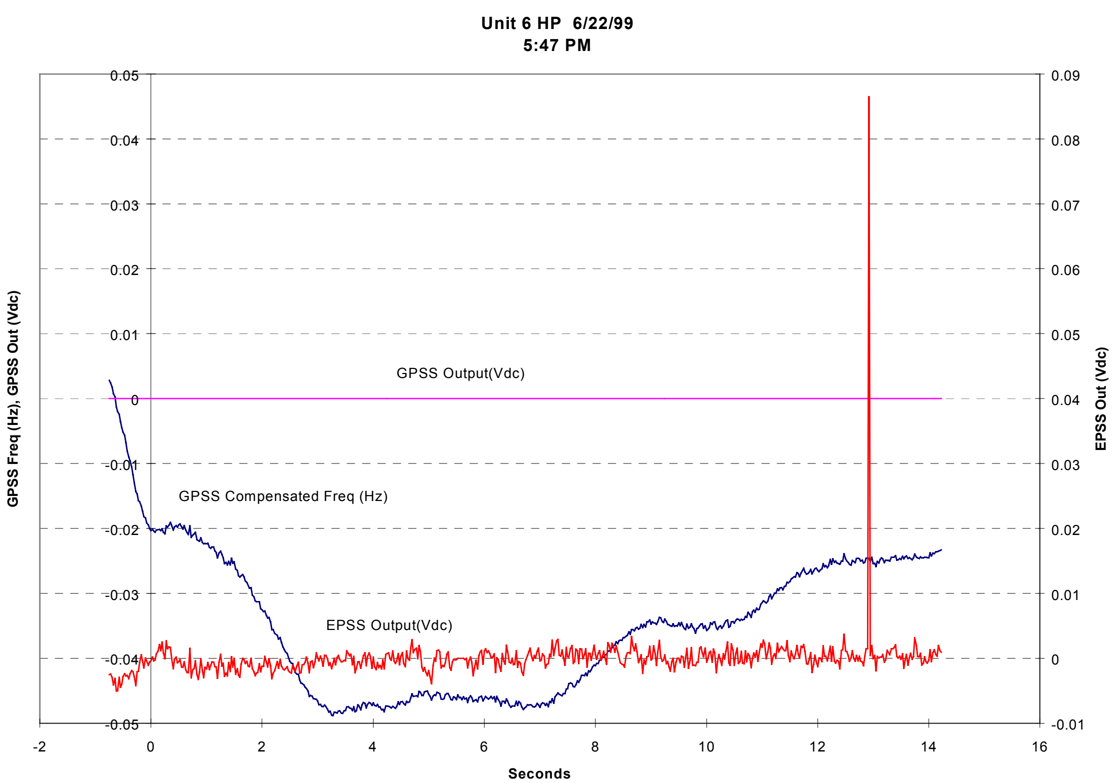
Unit 6 HP 6/22/99
4:46 PM

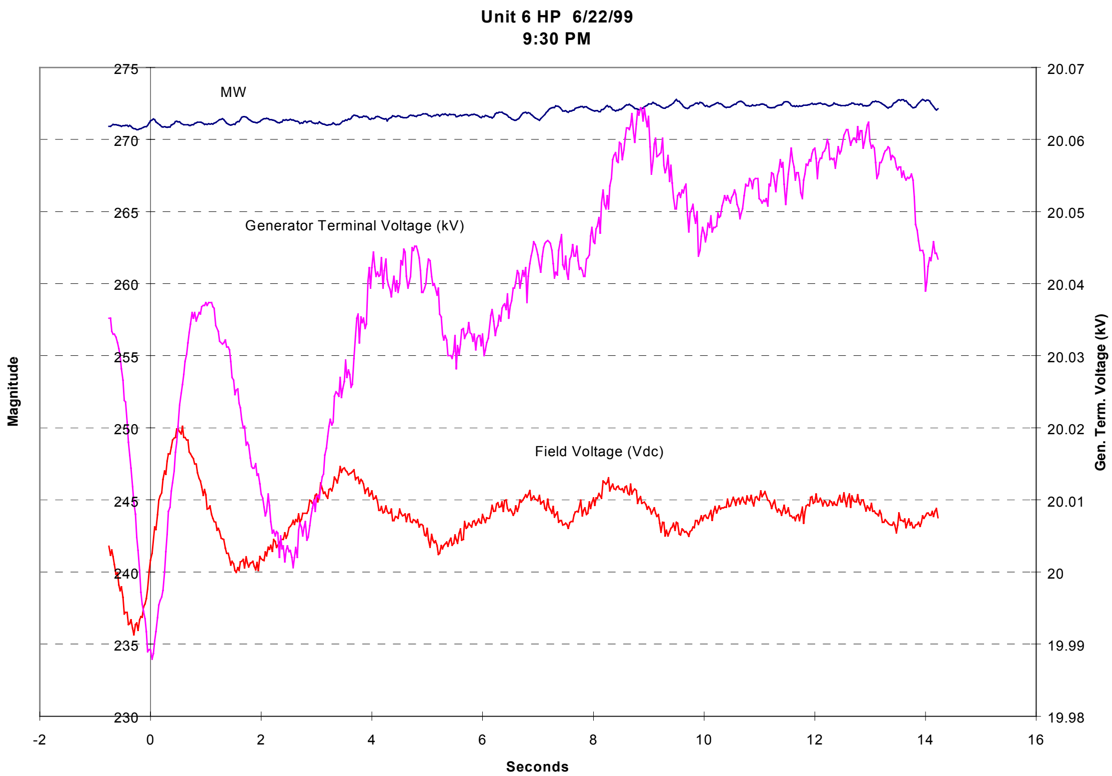


Unit 6 HP 6/22/99
4:46 PM

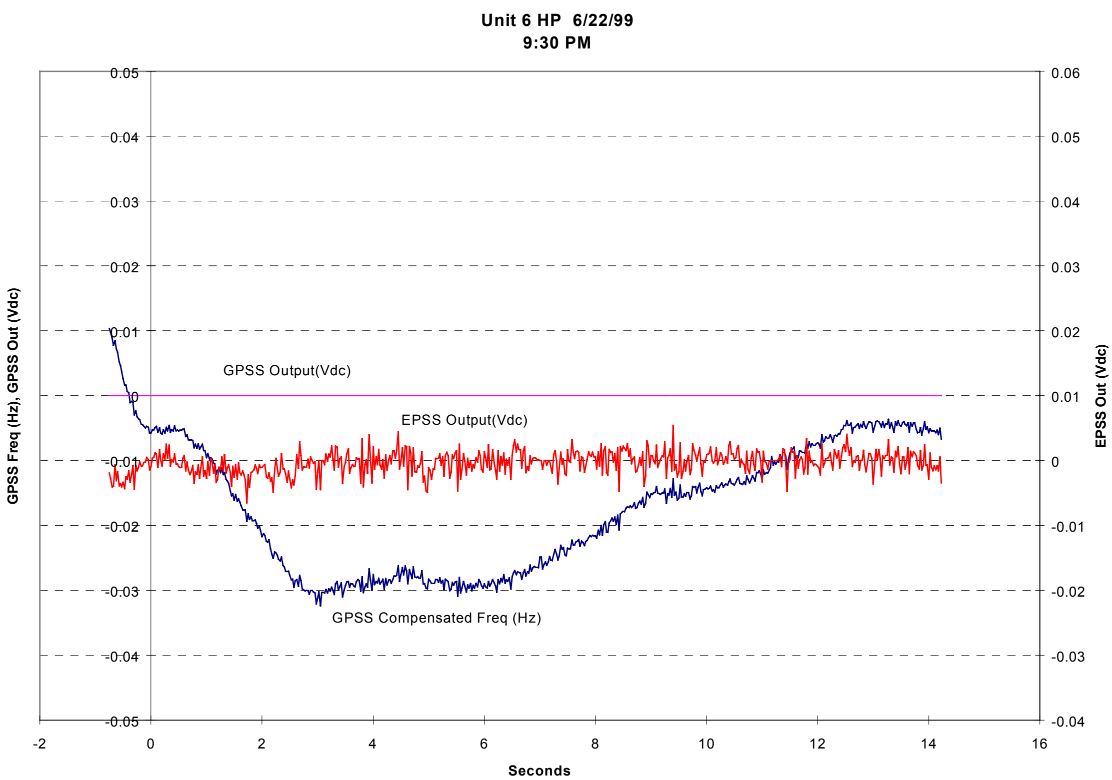



Unit 6 HP 6/22/99
5:47 PM
MW
Generator Terminal Voltage (kV)
Field Voltage (Vdc)
Magnitude
Gen. Term. Voltage (kV)
Seconds
280
275
270
265
260
255
250
245
240
235
230
20.2
20.18
20.16
20.14
20.12
20.1
20.08
20.06
20.04
20.02
20
-2
0
2
4
6
8
10
12
14
16

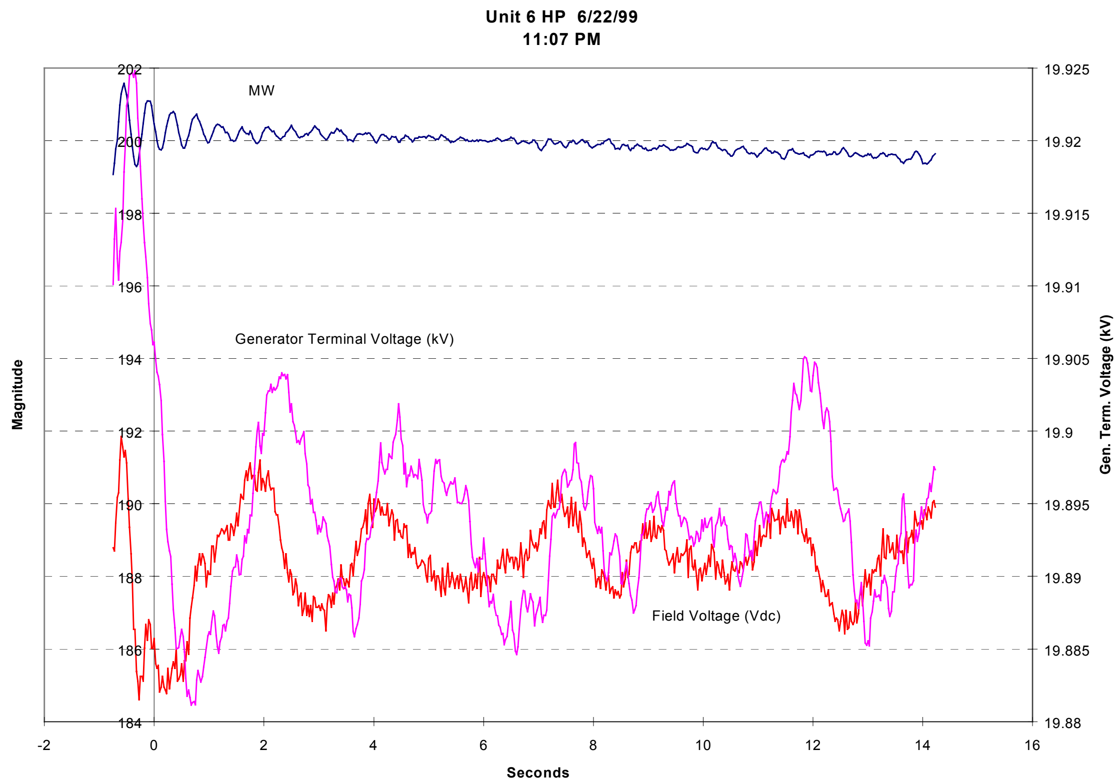

Unit 6 HP 6/22/99
5:47 PM
GPSS Output(Vdc)
GPSS Compensated Freq (Hz)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-2
0
2
4
6
8
10
12
14
16



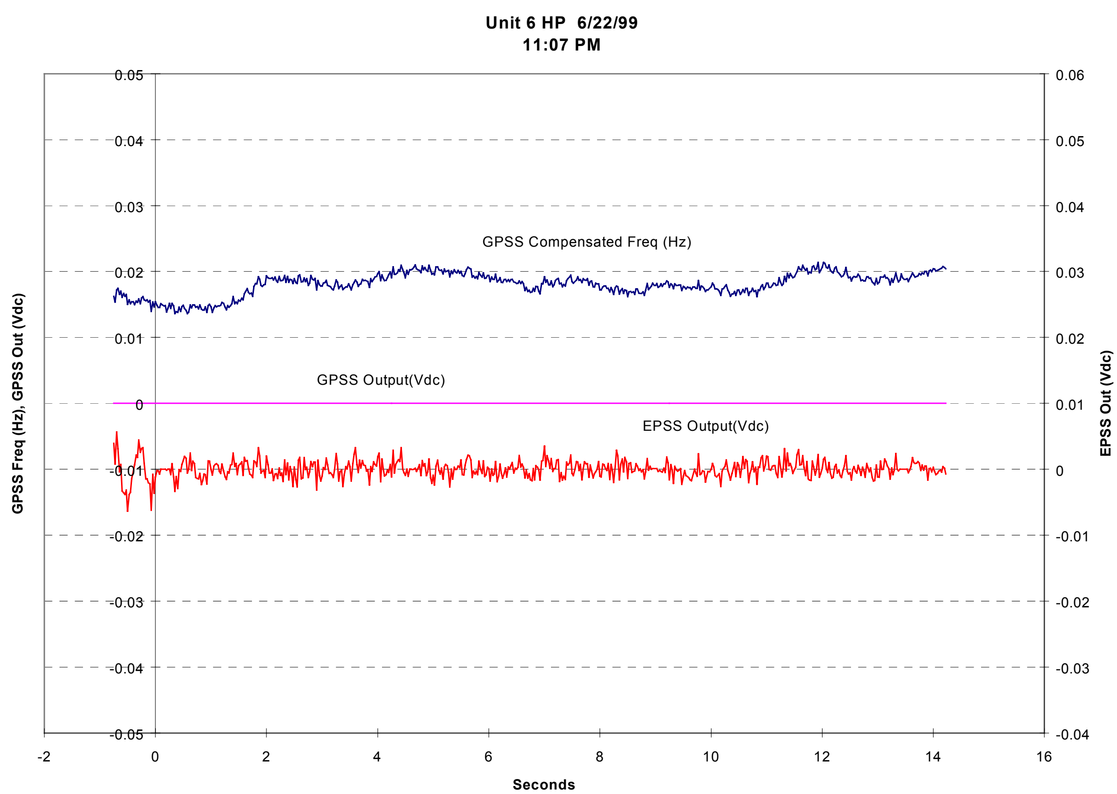
Unit 6 HP 6/22/99
9:30 PM
MW
Generator Terminal Voltage (kV)
Field Voltage (Vdc)
Magnitude
Gen. Term. Voltage (kV)
Seconds



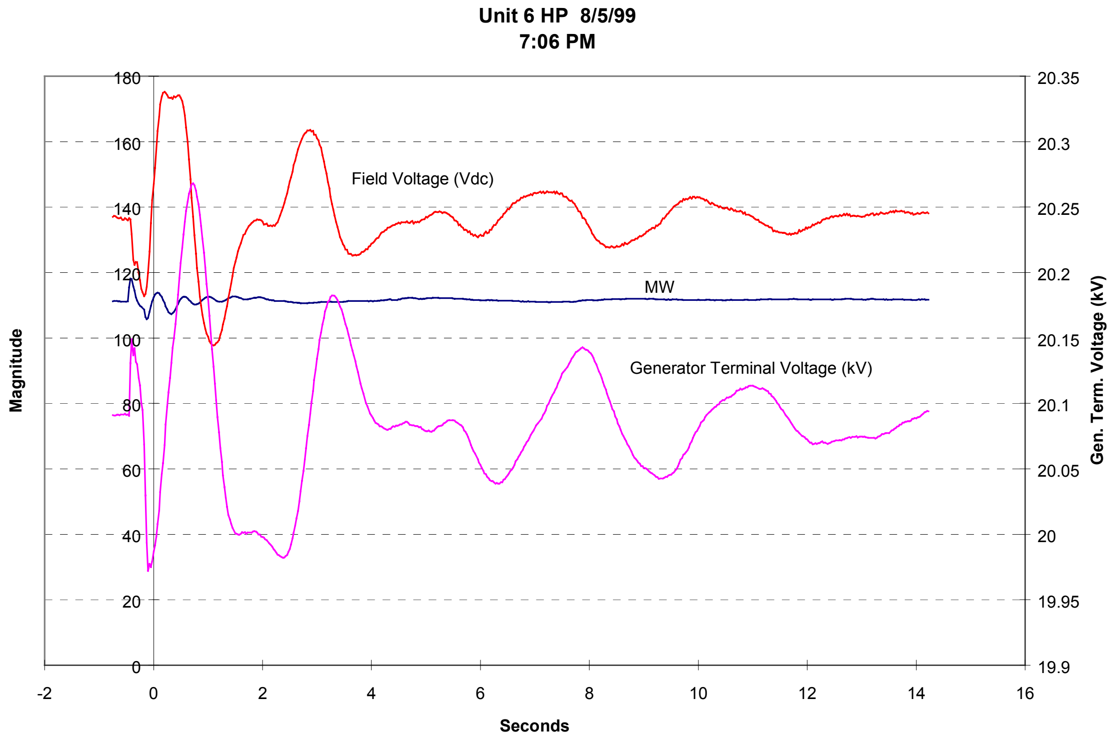
Unit 6 HP 6/22/99
9:30 PM
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Compensated Freq (Hz)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds

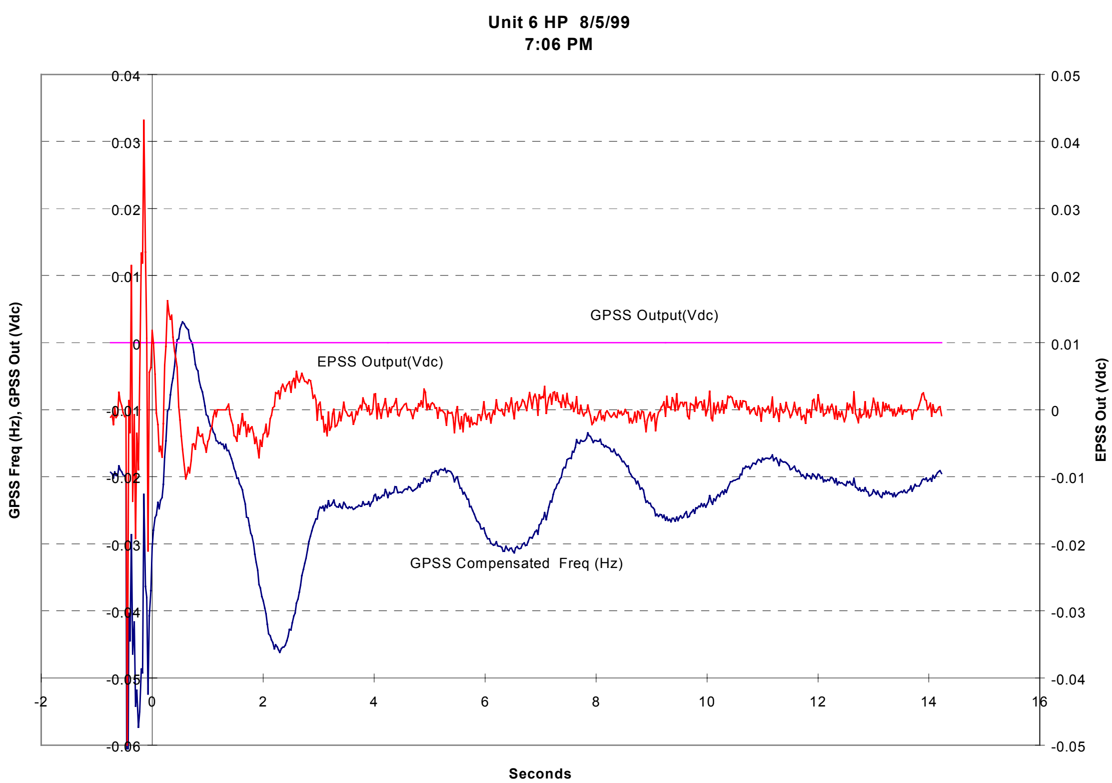


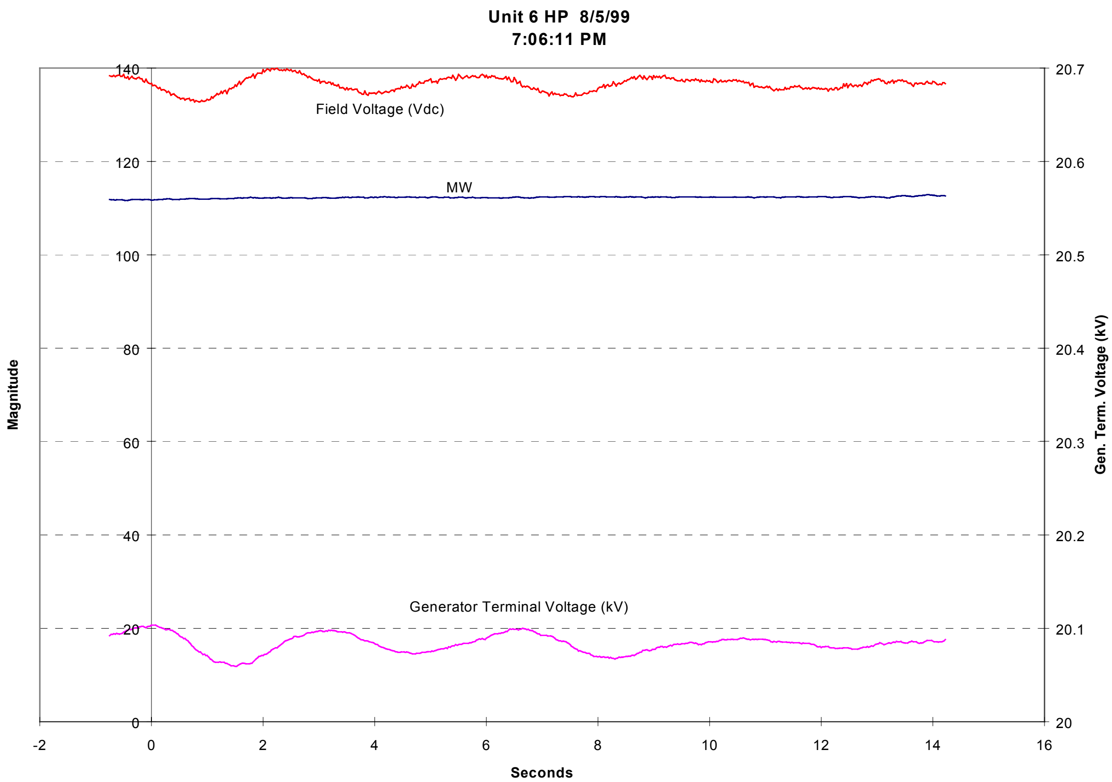
Unit 6 HP 6/22/99
11:07 PM
MW
Generator Terminal Voltage (kV)
Field Voltage (Vdc)
Magnitude
Gen. Term. Voltage (kV)
Seconds
202
200
198
196
194
192
190
188
186
184
19.925
19.92
19.915
19.91
19.905
19.9
19.895
19.89
19.885
19.88
-2
0
2
4
6
8
10
12
14
16



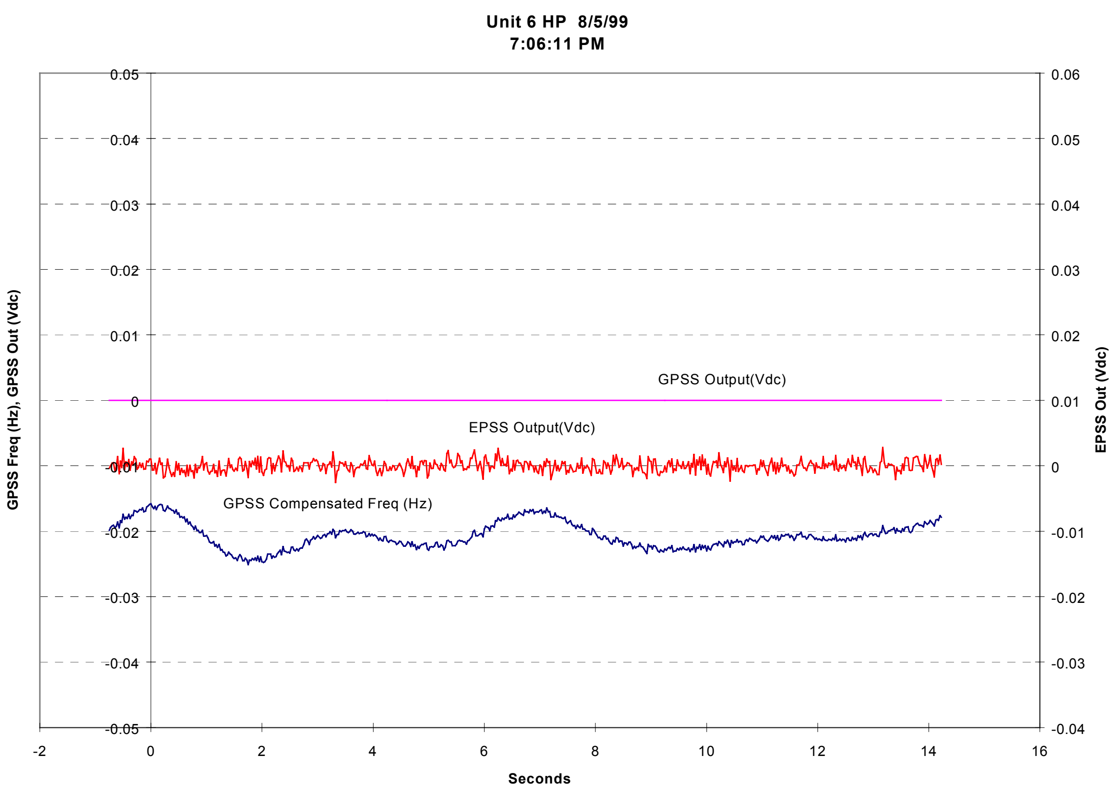
Unit 6 HP 6/22/99
11:07 PM
GPSS Compensated Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16


Unit 6 HP 8/5/99
7:06 PM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
Magnitude
Gen. Term. Voltage (kV)
Seconds

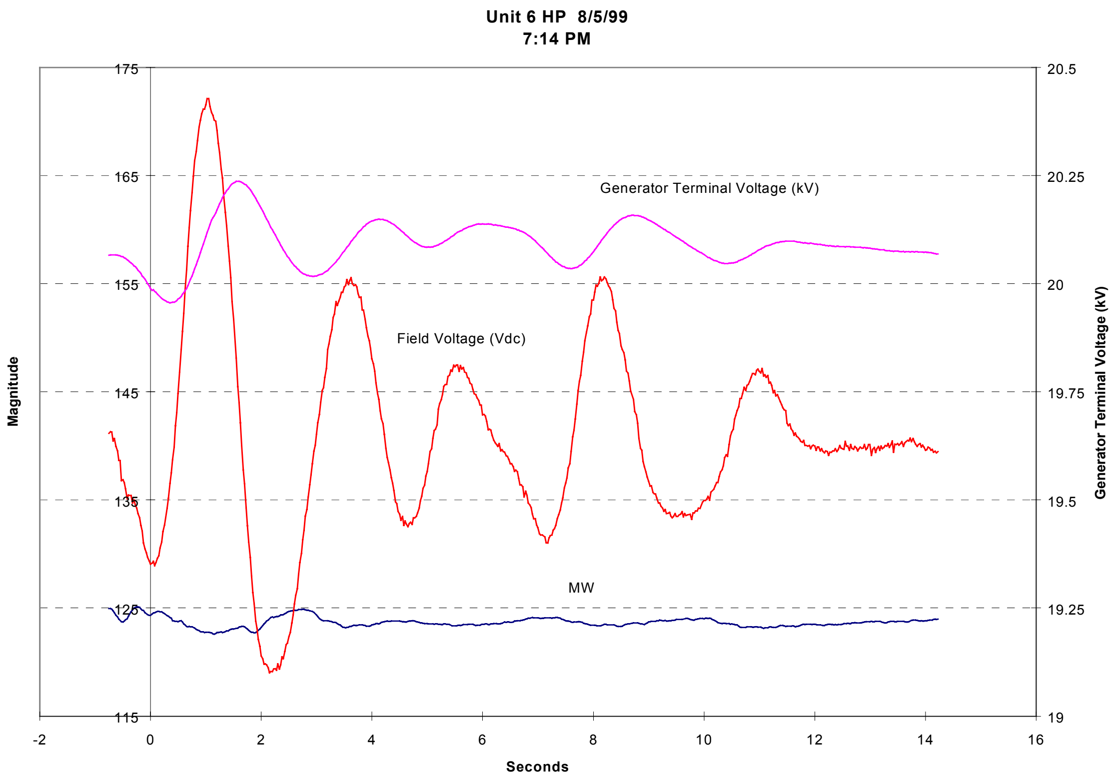

Unit 6 HP 8/5/99
7:06 PM
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Compensated Freq (Hz)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds

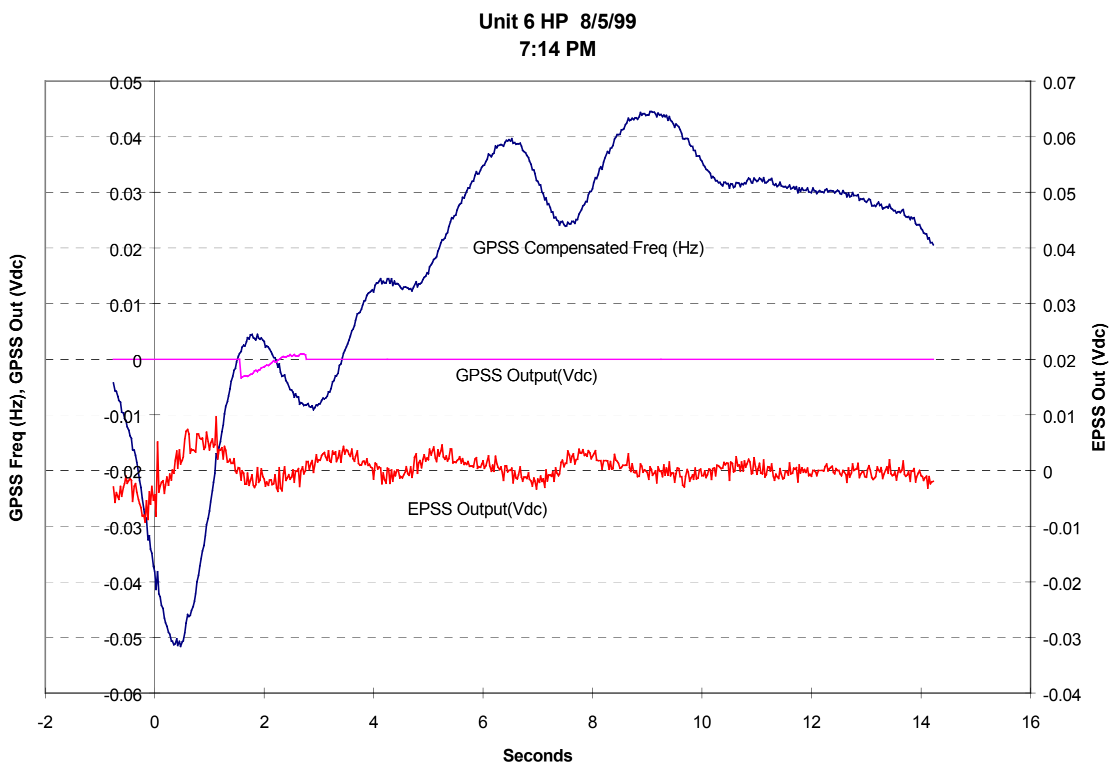


Unit 6 HP 8/5/99
7:06:11 PM
Field Voltage (Vdc)
MW
Generator Terminal Voltage (kV)
Magnitude
Gen. Term. Voltage (kV)
Seconds

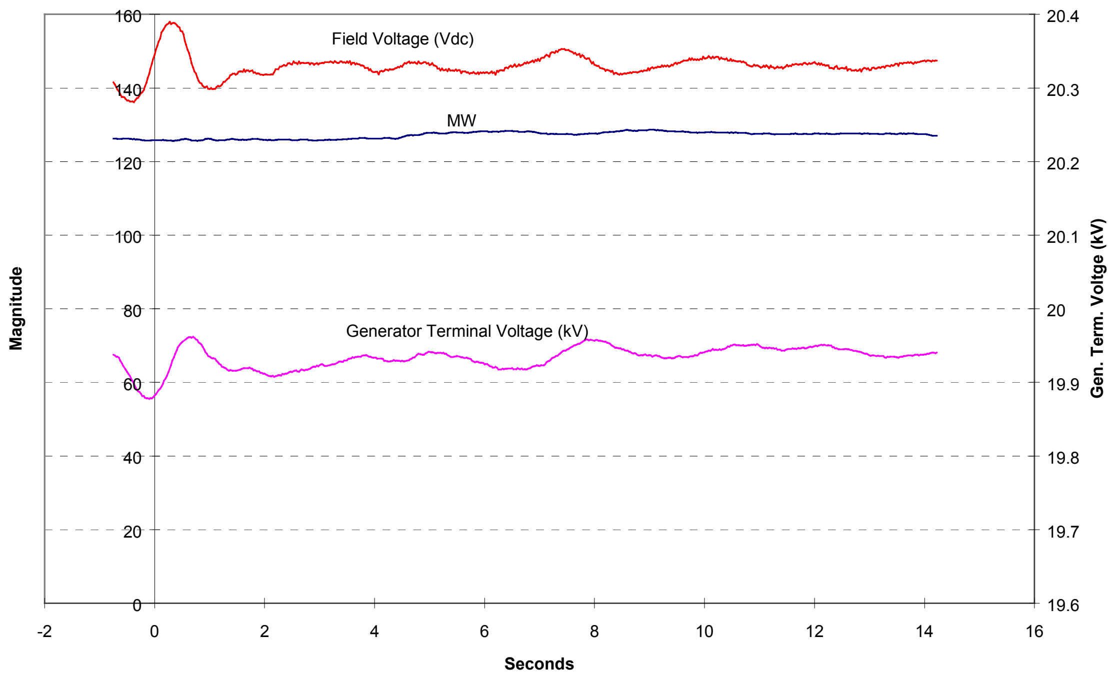


Unit 6 HP 8/5/99
7:06:11 PM
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Compensated Freq (Hz)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds

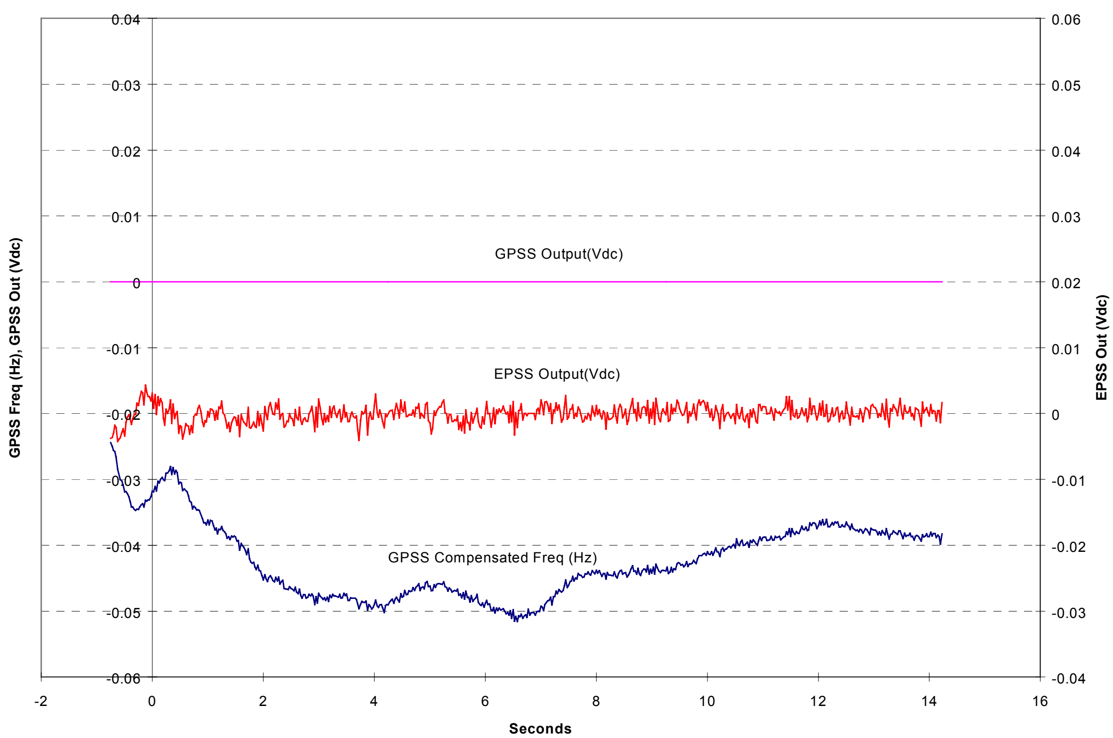

Unit 6 HP 8/5/99
7:14 PM
Generator Terminal Voltage (kV)
Field Voltage (Vdc)
MW
Magnitude
Generator Terminal Voltage (kV)
Seconds

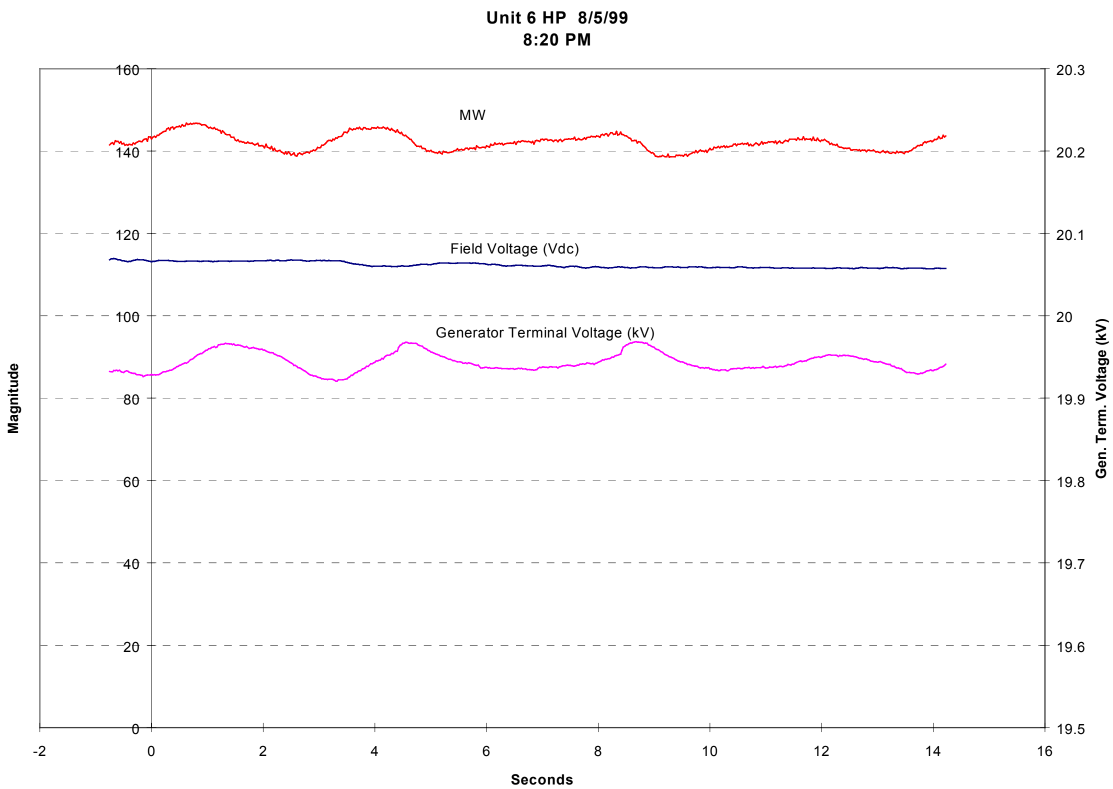

Unit 6 HP 8/5/99
7:14 PM
GPSS Compensated Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds

Unit 6 HP 8/5/99
7:57 PM

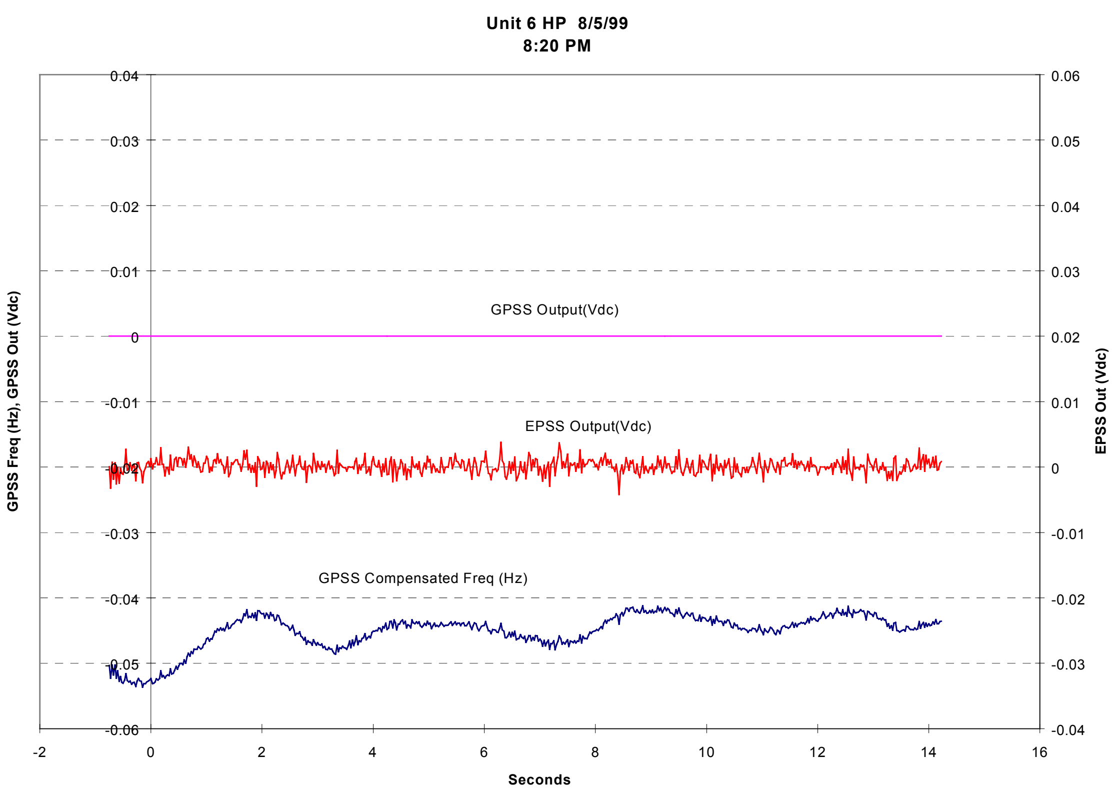


Unit 6 HP 8/5/99
7:57 PM



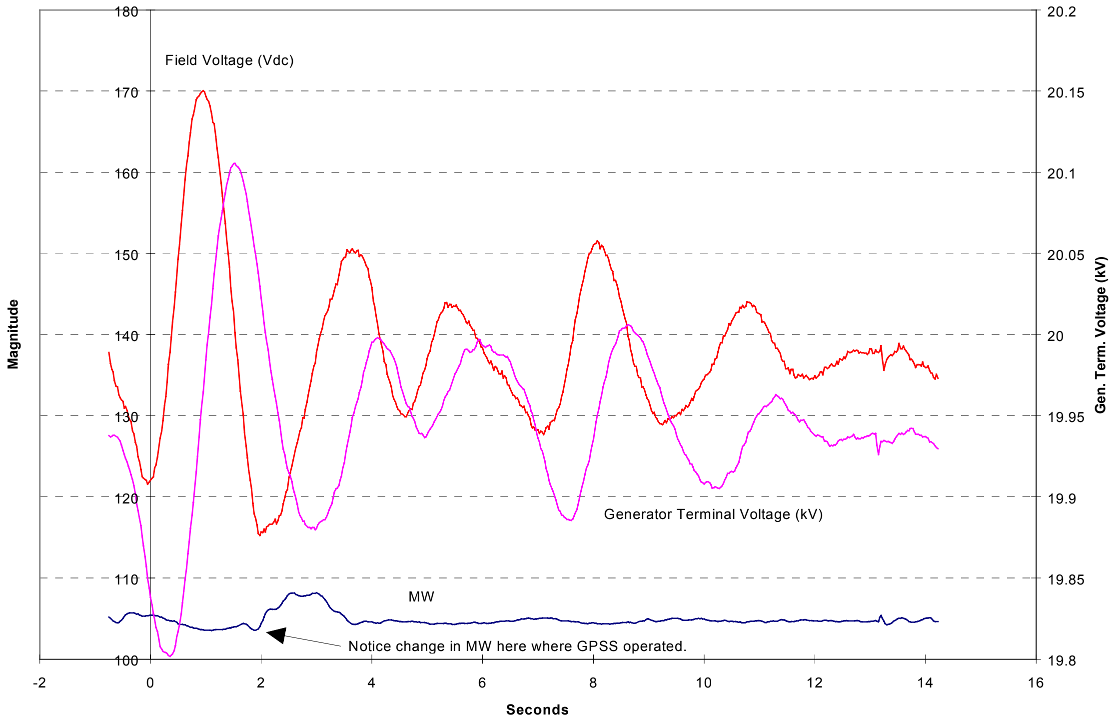


Unit 6 HP 8/5/99
8:20 PM
MW
Field Voltage (Vdc)
Generator Terminal Voltage (kV)
Magnitude
Gen. Term. Voltage (kV)
Seconds
160
140
120
100
80
60
40
20
0
20.3
20.2
20.1
20
19.9
19.8
19.7
19.6
19.5
-2
0
2
4
6
8
10
12
14
16

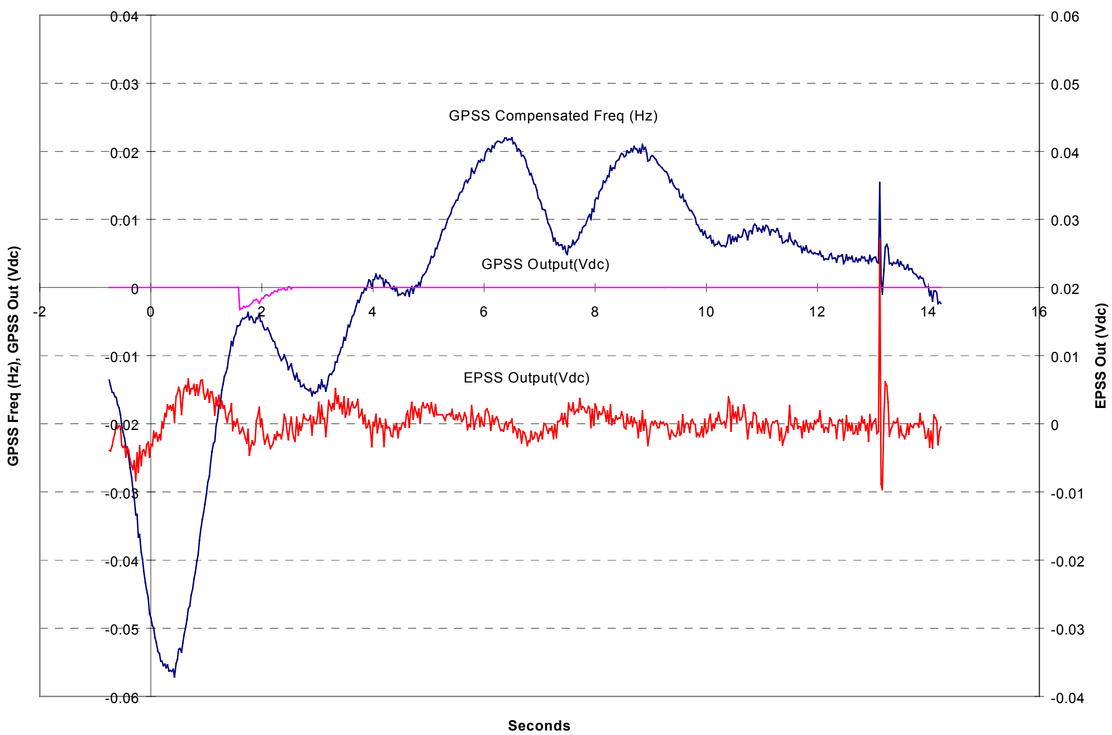


Unit 6 HP 8/5/99
8:20 PM
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Compensated Freq (Hz)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16

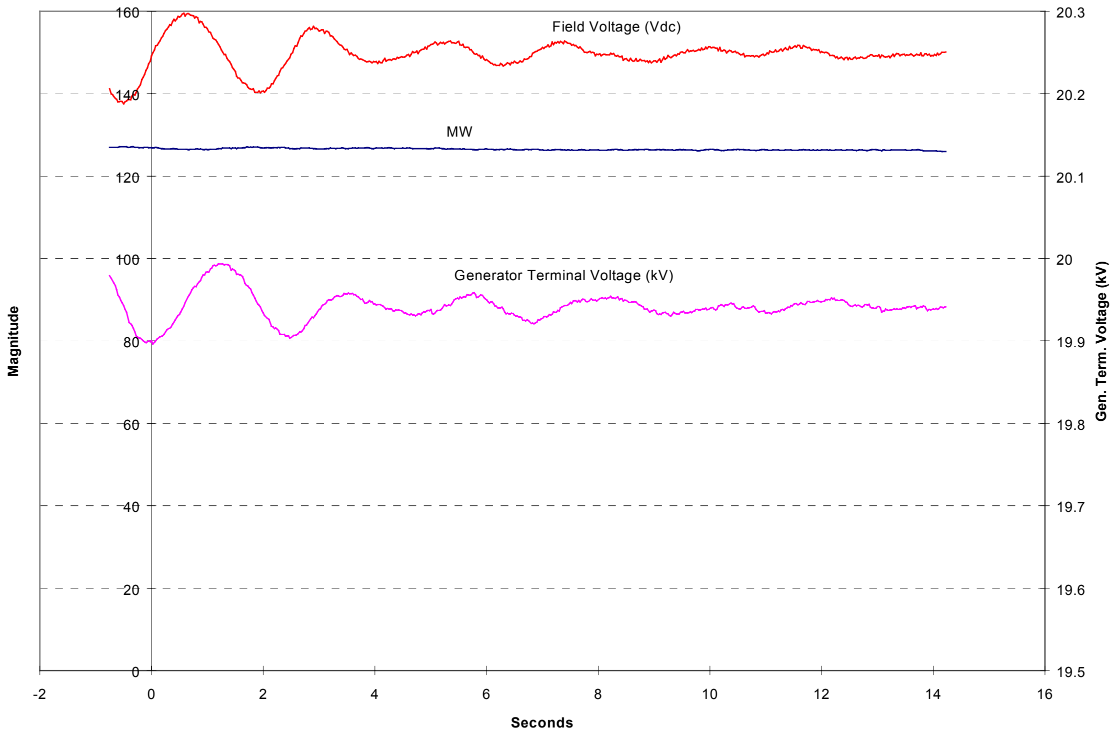
Unit 6 HP 8/5/99
8:25 PM



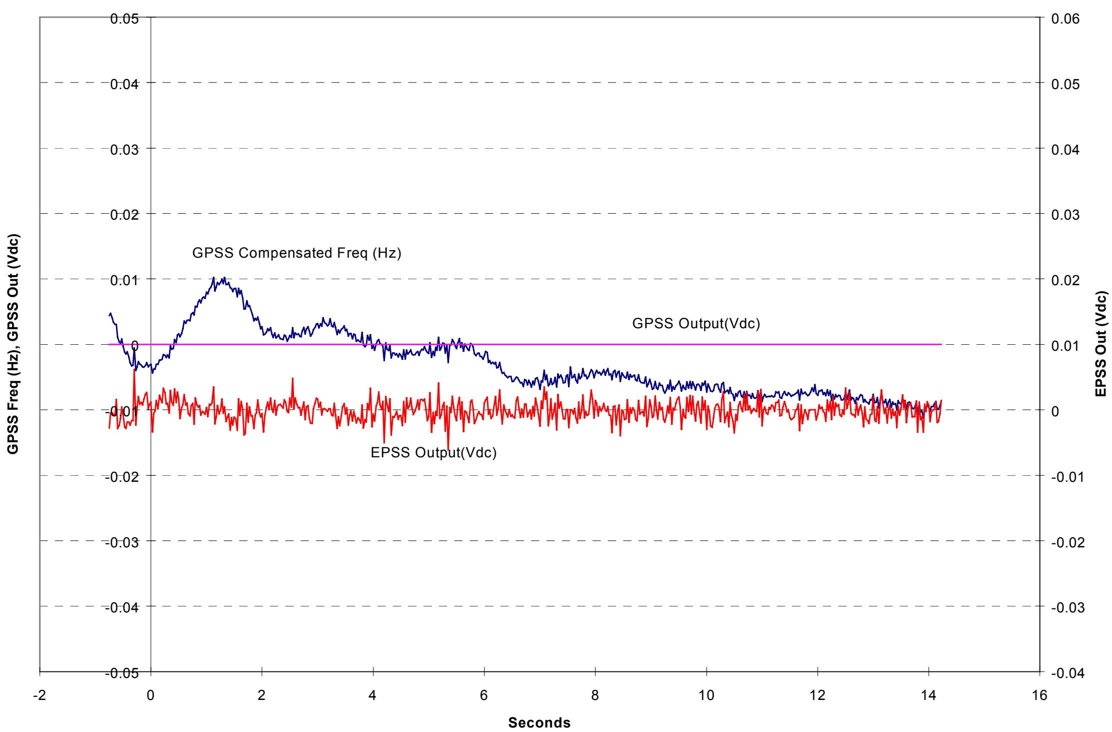
Unit 6 HP 8/5/99
8:25 PM



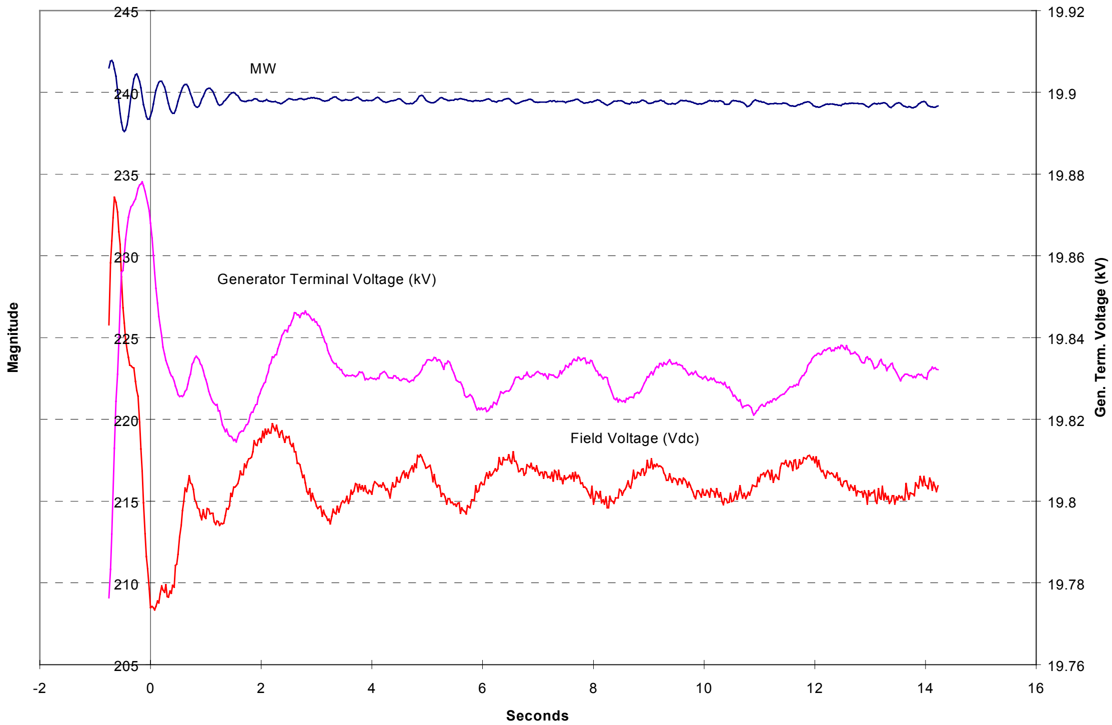
Unit 6 HP 8/5/99
10:56 PM



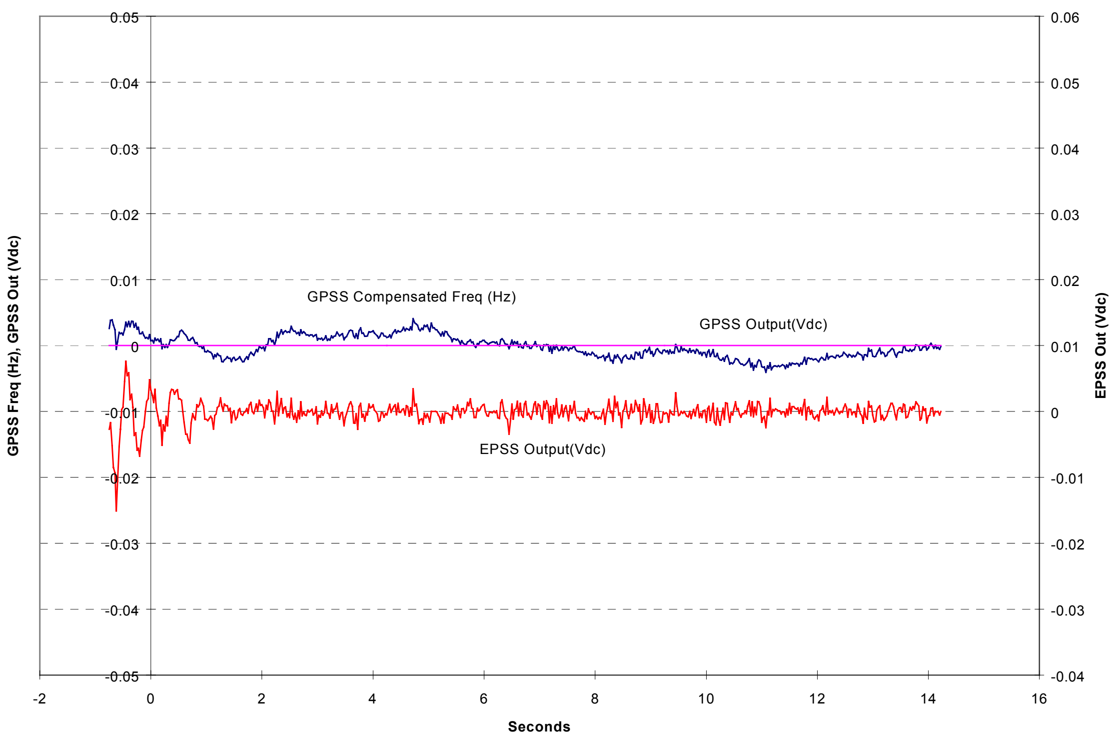
Unit 6 HP 8/5/99
10:56 PM

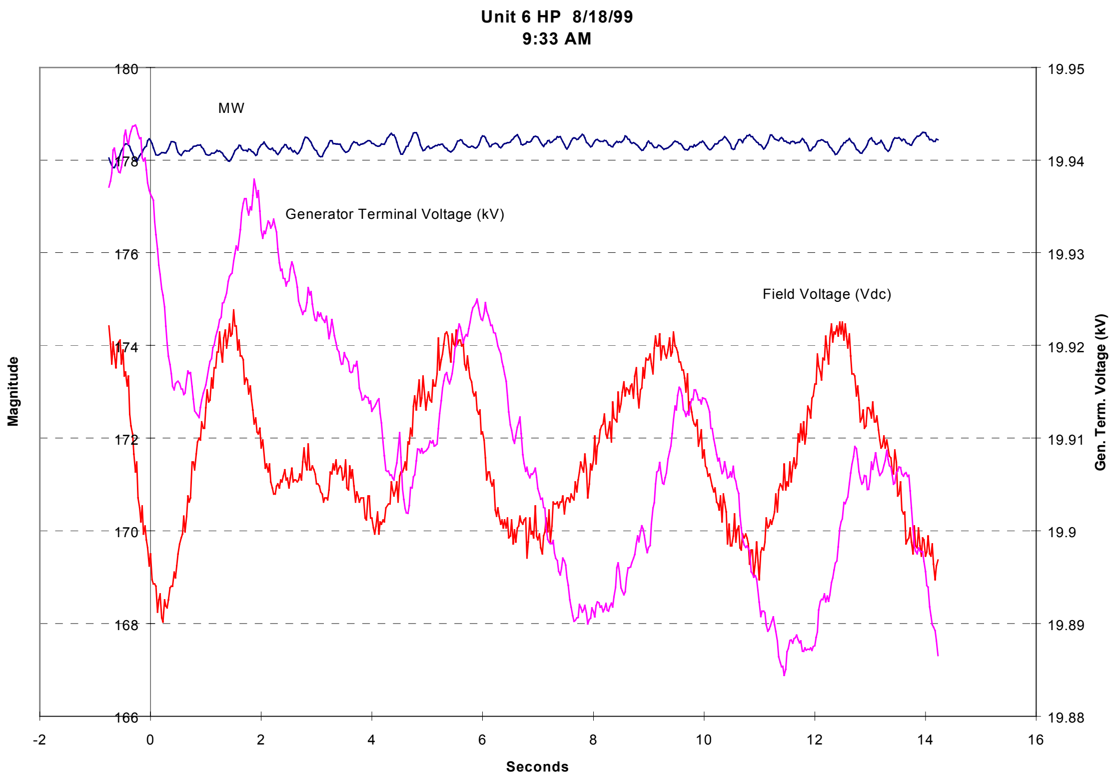


Unit 6 HP 8/17/99
11:03 AM

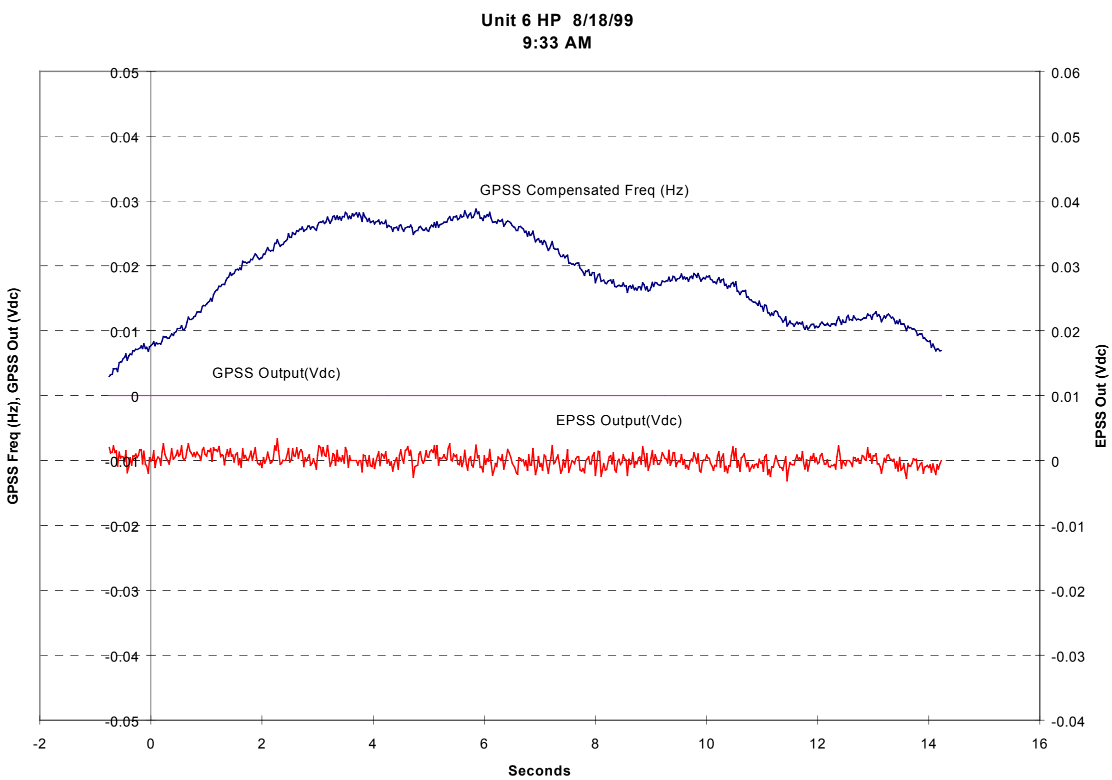


Unit 6 HP 8/17/99
11:03 AM

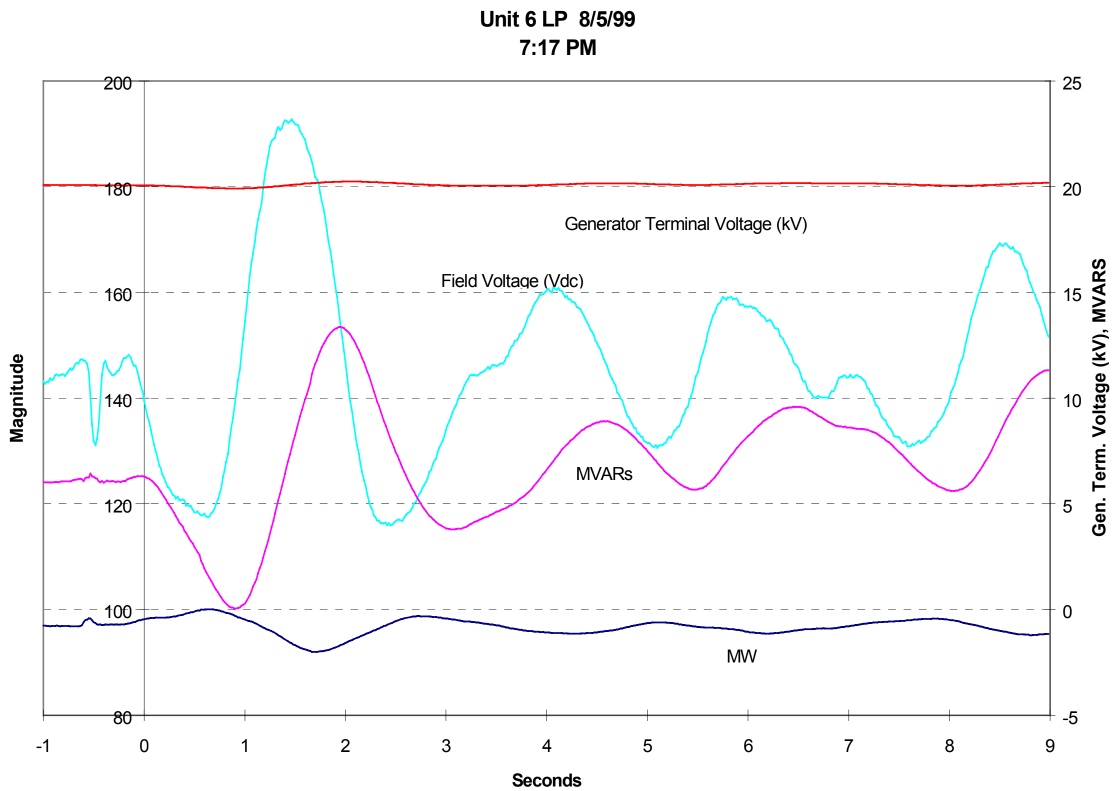


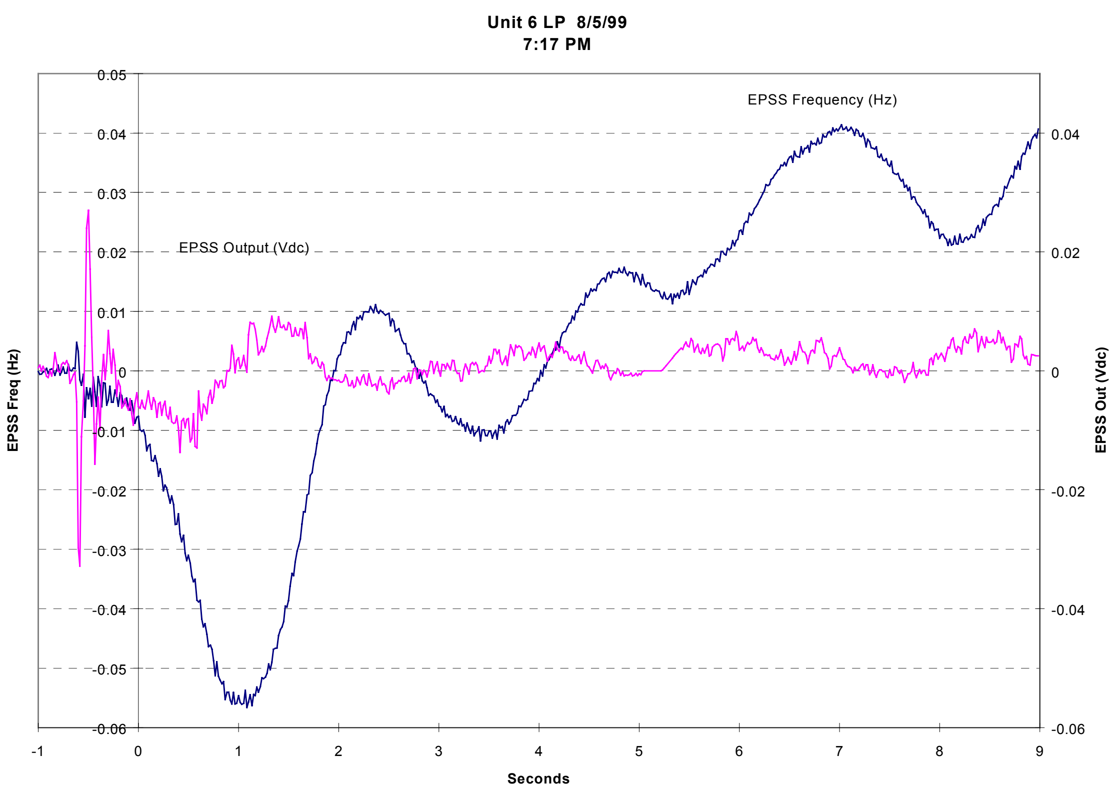


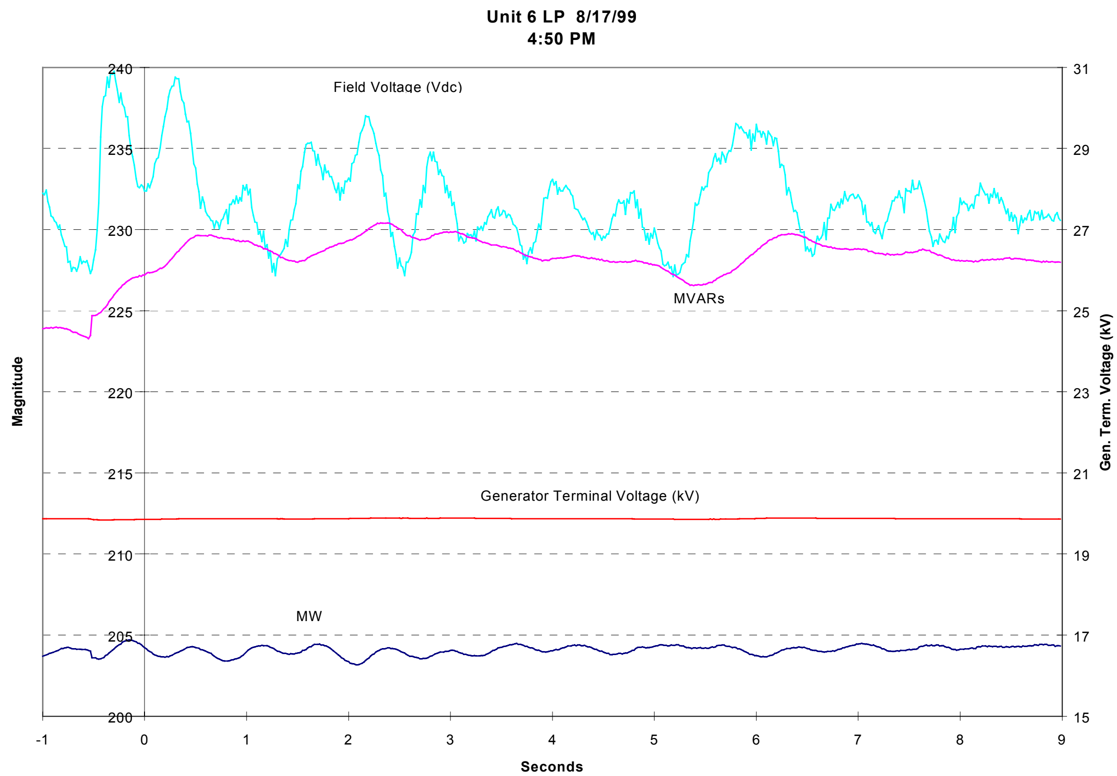
Unit 6 HP 8/18/99
9:33 AM
MW
Generator Terminal Voltage (kV)
Field Voltage (Vdc)
Magnitude
Gen. Term. Voltage (kV)
Seconds
180
178
176
174
172
170
168
166
19.95
19.94
19.93
19.92
19.91
19.9
19.89
19.88
-2
0
2
4
6
8
10
12
14
16

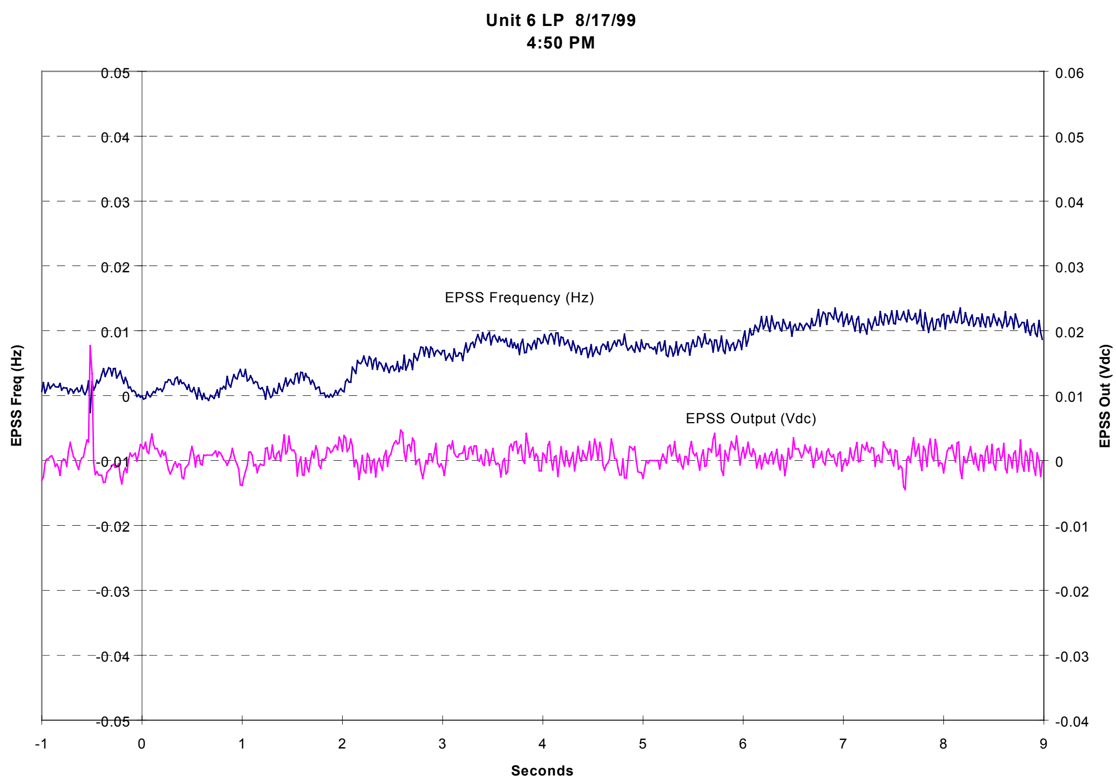


Unit 6 HP 8/18/99
9:33 AM
GPSS Compensated Freq (Hz)
GPSS Output(Vdc)
EPSS Output(Vdc)
GPSS Freq (Hz), GPSS Out (Vdc)
EPSS Out (Vdc)
Seconds
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-2
0
2
4
6
8
10
12
14
16


Unit 6 LP 8/5/99
7:17 PM
Magnitude
Gen. Term. Voltage (kV), MVARS
Generator Terminal Voltage (kV)
Field Voltage (Vdc)
MVARs
MW
Seconds
200
180
160
140
120
100
80
25
20
15
10
5
0
-5
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 8/5/99
7:17 PM
EPSS Freq (Hz)
EPSS Out (Vdc)
EPSS Frequency (Hz)
EPSS Output (Vdc)
Seconds
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-1
0
1
2
3
4
5
6
7
8
9


Unit 6 LP 8/17/99
4:50 PM
Field Voltage (Vdc)
MVARs
Generator Terminal Voltage (kV)
MW
Magnitude
Gen. Term. Voltage (kV)
Seconds


Unit 6 LP 8/17/99
4:50 PM
EPSS Frequency (Hz)
EPSS Output (Vdc)
EPSS Freq (Hz)
EPSS Out (Vdc)
Seconds